

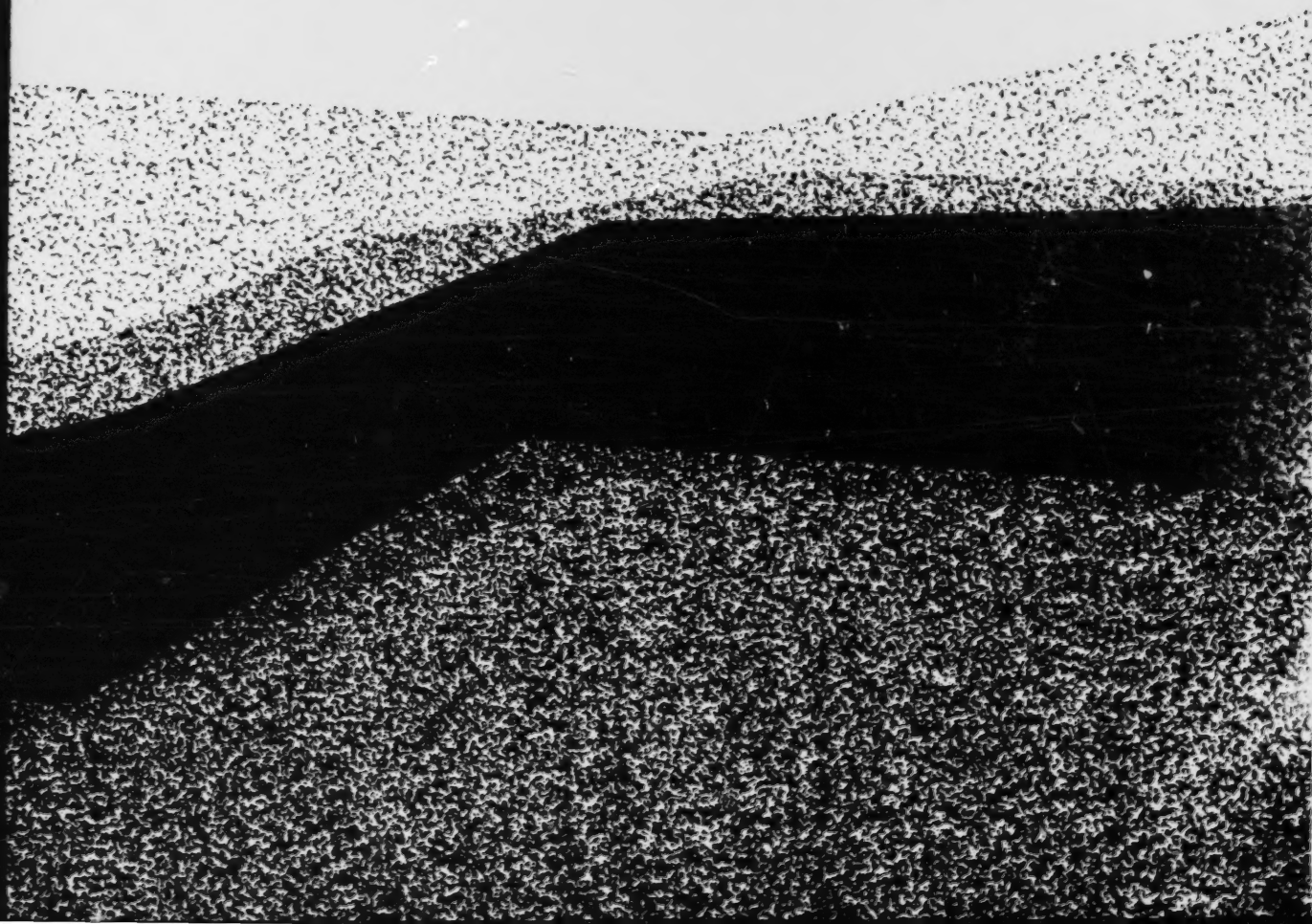
Centre for
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Queen's University
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Secondary Supply of Copper and Ferrous Metals and Canadian Metal Markets

KENNETH R. STOLLERY

Technical Paper No. 3





**SECONDARY SUPPLY OF COPPER AND FERROUS METALS
AND
CANADIAN METAL MARKETS**

by

Kenneth R. Stollery

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Preface

The CRS technical paper series is designed to present detailed and technical studies and analyses that provide background data for understanding specific aspects of the Canadian mineral industry. It is hoped that this series will contribute to an understanding of some of the complicated interrelationships that underlie the industry, and have economic and policy implications that bear consideration by policy makers in industry and government.

In this study the author looks at existing markets for copper and ferrous scrap metals, primarily in the USA, and the effects of these markets on demand and prices for Canadian primary metal exports. Both descriptive and analytic methods are employed. Supply and demand data are provided for the recent decades along with descriptions of scrap market operations. Economic models are also used, to analyze the market interrelationships. Finally, an econometric model is used to derive empirical estimates of the relationships between scrap markets and Canadian primary metal exports, and to estimate the effects of exogenous variables such as energy prices.

The detailed analyses will be of interest to experts in copper and iron ore marketing and in the secondary metal supply industry, as well as to policy makers in industry and government.

Views expressed are those of the author, and do not necessarily represent those of the Centre for Resource Studies or its sponsors.

Margot J. Wojciechowski
Centre for Resource Studies



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Foreword

The sources used for this study are mainly in the public domain. The exception is a confidential study by the International Iron and Steel Institute on projected iron ore, coal and scrap supply and demand, lent by Peter Nixon of Algoma Steel. I obtained help and encouragement from many others. George Miller, Andrew Freyman, Charles Pye, and Nancy Olewiler, members of the staff at the Centre for Resource Studies, gave valuable suggestions in the formative stage of the study and read an earlier draft of the manuscript. I also benefited from discussion with Don Barnett of Windsor University, Dan Bezeau and Marty Martinello of Intermetco, Keith McPhail of Inco, Paul Warrington, D.J. McIntyre and J.R. Hampton of Noranda, Bill Wardrope of Stelco, John Paulowich of Dofasco, and Jack Rosen of Rosen Metals, Kitchener, as well as William Hogan of Fordham University, R. Goodman of Industry, Trade and Commerce and R. McInnis of Energy, Mines and Resources in Ottawa. Valuable editorial suggestions and assistance came from Fern Miller and Lurna Tallman, and research assistance from Dana Danaitis, Guillermo Garrido, Eduardo Palomino, and Peter Tsonis. Responsibility for errors is, of course, mine.

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SUMMARY

In investigating the relationships between Canadian primary metal exports and U.S. scrap markets for copper and ferrous metal, some of the important conclusions are as follows.

Copper

Because of the large copper concentrate exports to Japan, only about 35 to 40 percent of Canadian copper production competes directly with U.S. copper scrap. However, U.S. scrap has an influence on world copper prices which affects the value of all refined copper exports.

Scrap copper is composed of home, new and old scrap. In copper, home scrap is about 30 percent, new scrap about 45 percent, and old scrap about 25 percent of the total, with new scrap rising slowly in proportion. Usually home and new scrap are regarded as being insensitive to scrap price changes; however, we found a significant positive response, with an elasticity of .36. Because the old scrap response is low, total scrap supply does not respond strongly to scrap price, resulting in dramatic scrap price changes with changes in overall copper demand. In our sample (1958-79) we found free market (COMEX, LME and scrap) copper prices to change approximately in proportion to changes in U.S. and European durable manufacturing activity. The number 2 scrap price was found to vary almost in proportion to the London Metal Exchange copper price, except in periods of U.S. copper scrap export controls. On average, through 1979 the producer price varied so as to halve the gap between it and the COMEX or LME price in a given year.

On the basis of our estimated copper model, we calculated the effects of scrap supply on copper prices. In the past, a 10 percent rise in U.S. and European manufacturing activity has been associated with, on average, a 12.3 percent increase in both the LME and COMEX prices. With both new and old scrap fixed in supply, we estimated the increase would be about 15.7 percent, the difference being the effect of scrap supply increases in dampening copper prices.

Although primary copper production is energy intensive and secondary copper considerably less so, energy price changes have affected neither copper prices nor the scrap market share. Copper prices do not change with energy prices because, although costs rise, demand falls at the same time as a result of energy-induced recession.

Energy prices are potentially more important in conjunction with the secular decline in primary copper yields, which fell from .89 percent in 1949 to .49 percent in 1979. On average, a 1 percent fall in copper yields (from .50 percent to .495 percent, say) raises copper prices 1.7 percent, other things being equal. Because processing of lower-grade ore is more energy intensive, energy price changes also become more important as grade falls.

Ferrous Metal

Of the 50 to 60 million tonnes of Canadian iron ore production, 81 percent was exported in 1980. About half of these exports go to the USA (about 20-25 million tonnes), where they compete with scrap. U.S. ferrous scrap production of 89.7 million tonnes in 1979 represented more than six times the Canadian exports to that market. Because it competes with pig iron and not iron ore directly, a tonne of scrap substitutes for about 1.5 tonnes of iron ore. Scrap had about a 47 percent share of total metallics in steel furnaces and foundries in the USA in 1979.

Of the three scrap types, home scrap is most important in ferrous scrap, with about 48 percent of the total; new and old scrap represent 30 percent and 20 percent respectively. Home scrap supply rose until 1970, then fell with the introduction of the continuous casting steel finishing process. We found home scrap negatively related to the scrap price, because scrap represents an important cost of steel production, and increased scrap prices induce greater steel-making efficiency. Old scrap supply, while fairly constant in proportion in the post-war period, may fall somewhat in the future as the result of dramatic decreases in the weight of steel in automobiles, although this is unlikely to cause major shortages of purchased scrap.

The demand for scrap in steel furnaces responds somewhat to changes in the price of number 2 scrap; not by means of substitution within steel furnaces, but by varying the relative utilization rates of BOF and electric furnaces. The overall elasticity of scrap demand in U.S. steelmaking was low: an estimated $-.32$.

The response of old scrap to changes in scrap prices was found to be much lower than had been estimated by previous researchers and, in combination with the negative relationship of home scrap to the scrap price, gives a very low total supply elasticity, of .1 or less in a single year. Because scrap demand in steel furnaces is also inelastic, scrap prices change dramatically with changes in total steel production, number 2 scrap changing on average nearly 1.5 times as much as steel output.

Merchant pig iron and iron ore prices were also found to vary somewhat with steel output. The merchant pig iron price was found to be strongly negatively related to steel output, possibly indicating a significant degree of blast furnace economies of scale. The Lake Erie pellet price was not found to be responsive to steel output. This is not surprising, as this price is largely an intra-firm transfer price rather than market determined. However, an index of natural ore prices was found to vary somewhat with demand for total steel in the USA.

Because of these scale economies, and because of the ownership links between Canadian iron ore mines and U.S. steel plants, Canadian iron ore production expands more than proportionally when U.S. steel output expands, with a elasticity of about 1.7. However, there appears to be little real substitution of iron ore for scrap in steelmaking. According to our estimation, a 1 percent increase in the price of number 2 scrap in the USA increases Canadian ore demand only .12 percent, with steel output constant.

Finally, the low estimated elasticities of scrap supply and demand in the USA mean the effects of proposed subsidy programs to encourage recycling and increase the share of scrap in metal markets will likely have little success within the context of the present commercial scrap industry structure. Although huge potential scrap sources remain to be exploited in North America, they are mostly of low-grade material and require a significant advance in processing technology before becoming commercially feasible sources of supply.



1. AN OUTLINE OF THE STUDY

The Purpose of the Report

There has recently been a strong resurgence of interest in the recycling of metals, especially in industrialized countries. This has occurred for several reasons. Metal reprocessing helps to reduce the consumption of nonrenewable resources. It also appears to have fewer harmful environmental effects than the extraction of virgin ores. From a global perspective it seems clear that an increase in the importance of secondary metal supply is desirable as a long-term policy objective. However, the design of policies aimed at achieving these long-term goals is predicated on an analysis of the structure of metal markets and the technical substitutability of secondary for primary metal. The timing of the changeover toward secondary metal is especially important. It is not unambiguously clear, for example, that Canadian national interest would be served, in the medium term, by the increased substitution of scrap for primary metal, since Canada is a major exporter of the latter.

The purpose of this report is to describe the structure of existing markets for secondary metal or scrap and to attempt to assess the effects of this market on output and price in the market for primary metal. Specifically, we are interested in how the scrap markets affect the demand and price received for Canadian primary metal exports. Because the USA is the major market for Canadian primary metal, the study concerns itself with scrap markets in that country. Since copper and iron ore are the most important metal markets for Canada in terms of value of exports, the study also focuses on these metals. The study attempts a blend of description and formal economic models.

An important characteristic of the relationship between primary and secondary metal is the degree to which scrap and primary metal can be used interchangeably by metal consumers. The degree of substitution itself depends on three major factors:

- i the technical characteristics of the scrap-using industry that limit the use of either scrap or primary metal;
- ii the institutional structure of the markets for primary and secondary metals;
- iii the responsiveness of scrap supply to changes in metal prices.

Technical considerations include, for example, limitations on the proportion of lower-grade scrap that can be used in steel furnaces, because of the need to limit the degree of impurities in the steel.

Structural features of metal markets affecting scrap-primary substitution include:

- i the degree of horizontal concentration in both primary and secondary markets and the ability of market participants to control prices and to limit competition;
- ii the degree of vertical integration - for example, the extent to which the ownership of Canadian iron mines by the major firms in the U.S. steel industry gives them a built-in preference for ore versus scrap.

The responsiveness of scrap supply to changes in metal prices is the third major factor in the relationship of scrap and primary metal. The distinguishing feature of scrap supply is the fact that the flow of scrap coming onto the market in a given time period depends on the stock of scrap available for processing at the beginning of that period. This dependence on stocks imparts a cyclical nature to scrap markets, and can affect the stability of primary metal markets.

The factors above determine the ways that scrap and primary metal interact as part of the overall North American metal markets. We also discuss the effects on both scrap and primary markets of the following exogenous changes:

- i techniques of both scrap generation and metal fabrication, such as the continuous casting of steel;
- ii energy prices;
- iii environmental policy in the USA.

For example, without attempting to forecast scrap or primary supply or demand, we estimate on the basis of an econometric model the effects of a dollar increase in U.S. electricity prices on prices of both scrap and primary copper.

The Research Method and Structure of the Report

We employ both descriptive and analytical research methods in the study. Chapter 2 describes the importance of the U.S. scrap industry in relation to Canadian primary copper and iron ore exports. Chapter 3 outlines the nature of the scrap industry, the operations of dealers and processors, and the basic adversary relationship to primary metal. The chapter also describes the industrial organization of both scrap and primary markets for copper and for ferrous metals in terms of the horizontal and vertical integration of their participants. The economic models employed for the analysis of the market interre-

relationships are introduced in chapter 4. Chapter 5 then employs two earlier studies of the U.S. copper industry plus an econometric model prepared for this report to attempt to derive empirical estimates of the relationship between scrap and Canadian primary copper exports, as well as to estimate the effects of the exogenous changes above. Chapter 6 does parallel analysis for the steel and ferrous scrap industries, and chapter 7 offers some conclusions.

Scrap Definitions and Grades

Common Scrap Definitions

Home or revert scrap: recycled within the steel mill or fabricating plant and returned automatically to the metal manufacturing cycle without undergoing a market transaction.

Purchased scrap: either new or old scrap material that is processed by a secondary dealer or refiner and undergoes a market transaction.

Prompt, new, or return scrap: purchased scrap derived from waste in the fabricating process and usually returned directly to the secondary processor.

Old or obsolete scrap: recovered by scrap dealers from durable goods junked at the end of their useful life.

Copper Scrap Grades

Brass mill grade: virtually pure copper such as rods or clean, unalloyed wire. Does not require refining.

Number 1 copper: similar to brass mill grade but slightly less pure. Also must be not less than 1/16 of an inch thick or below #16 B and S wire gauge.

Number 2 copper: scrap with a nominal 96 percent copper content (less pure than No. 1 copper) which is first melted in an anode furnace and subsequently undergoes electrolysis to remove impurities.

Refinery brass and smelter grades: less pure than No. 2 copper and must be first treated in a cupola or blast furnace as part of the secondary recovery process.

Ferrous Scrap Grades

Number 1 heavy melting steel: wrought iron and steel, at least 4 inches thick, with dimensions not exceeding charging box size (60 x 24 in.).

Number 2 heavy melting steel: similar to number 1 heavy melting steel but it is at least 1/8 of an inch thick, black and galvanized iron. It is prepared to ensure compact charging and also may include prepared automotive scrap. Box size dimensions are 60 x 24 in. or 36 x 18 in.

Shredded scrap: old scrap that has been chewed up into fist-sized chunks and passed through a magnetic separator to remove nonferrous material. Almost equivalent to number 1 heavy melting steel.

Number 1 busheling: light steel scrap, such as stampings, new factory bushelings, and sheet clippings, etc. It may not exceed 12 inches in any dimension.

Bundled scrap: black and galvanized steel scrap, as well as clippings, old auto bodies and fenders, etc., compressed to charging box size and 75 lb./cu. ft. May be number 1 or number 2 depending on impurities.

2. CANADA AND U.S. SECONDARY METAL MARKETS

Introduction

Scrap is an integral part of most metal markets, comprising as much as 50 percent of the total in some industries. Canada both produces and consumes scrap, but our restricted market limits the generation of secondary metal relative to the huge potential in the USA. Our major role remains that of primary producer, in competition with secondary metal.

This chapter outlines the importance to Canada of its primary exports, the importance of the U.S. market for such exports, and the role of scrap generation as competition for Canadian exports. Because of the structure of the iron ore market, we will discuss the nonferrous and ferrous markets in turn, outlining general costs and benefits to Canada from increased metal recycling.

Canadian Nonferrous Metal Production and Exports

Canada is a world-ranking producer of primary nonferrous metals. Total nonferrous metal production value was \$6.1 billion in 1979 and \$6.3 billion in 1980. Of these totals, \$1.5 and \$1.8 billion respectively were from copper, \$.8 and \$1.7 billion were from nickel, and \$1.1 and \$.8 billion were from zinc. By comparison, total crude petroleum production value was \$7.6 billion in 1979 and \$9.1 billion in 1980¹. In terms of world mine production, table 1 shows that Canada in 1979 was top zinc producer, second largest nickel producer (down from first because of strikes during the year), and fourth largest aluminum, copper, and lead producer.²

Canada is also a large exporter of nonferrous metals, having a small domestic market. Of the five major nonferrous base metals, more than 60 percent of primary production was exported in 1979, and overall mineral exports represented 28.7 percent of total exports in that year.³ Exports can occur at three stages of processing: mining, which produces a concentrate; the furnace smelting of the ore to produce blister metal, or matte; and the electrolytic refining of the matte into the final product. In copper, for example, from 1976 to 1979 an average 38 percent of mine production was exported directly in the form of concentrates.⁴ The same pattern occurs in the other major nonferrous metals with the exception of aluminum, which Canada does not mine but only refines.

TABLE 1. WORLD PRODUCTION OF PRINCIPAL NONFERROUS METALS, 1979
(thousand tonnes)

Country	Aluminum (refined)	Copper (mine)	Lead (mine)	Nickel (mine)	Zinc (mine)
Australia	424.5	234.2	415.6	74.0	530.0
Canada	860.3	643.8	315.8	131.6	1148.5
Chile		1060.6			
Japan	1010.4				243.3
New Caledonia				81.3	
Norway	673.3				
Peru		398.0			490.0
S. Africa		190.6			
USA	4549.5	1443.6	525.6	13.7	267.3
USSR	2375.0	885.0	525.0	152.5	770.0
Zaire		377.0			
Zambia		600.0			
World	15118.7	7606.8	3512.7	704.6	5977.8
Canada's share	5.7%	8.5%	9.0%	18.7%	19.2%
Canada's position	4	4	4	2	1

Source: Canada, Department of Energy, Mines and Resources, Canadian Mineral Survey, 1979, Ottawa, 1980, p. 9.

If the concentrate is not exported directly, it goes to one of five smelters in Canada, two of which are confined to nickel-copper ore. These smelters are owned by large mining companies in Canada, and are located near major ore-bodies. The Noranda Mines smelter, for example, obtains 20 percent of its feed from its own mines, 30 percent from affiliated companies, and the remainder on a custom basis.

From the smelting stage, the copper matte usually goes directly to the refinery, with virtually no trade taking place in blister metal. Three companies, Noranda, Inco and Texasgulf (now Kidd Creek Mines), have refineries in Canada. Refined metal exports, in contrast to concentrates, tend to find their major market in the United States. Even in copper, where export sales to Europe have traditionally been very large, the geographical proximity and cultural similarity that has fostered heavy U.S. investment in the Canadian mineral industry has meant a special relationship with the U.S. market. Table 2 shows the importance of export markets, particularly the U.S. market, for Canadian base metal production.

The U.S. market is important to Canada, not only because of the amount of Canadian exports it directly absorbs, but because of the great effect U.S. production and consumption have on world metal prices. Although Canada is a major

nonferrous metal producer, for most metals the Canadian share is not large enough to have an influence on world prices. Essentially, Canadian producers are in the position of accepting prevailing world market prices in export sales,

TABLE 2. PRODUCTION, EXPORTS AND EXPORT DESTINATION OF MAJOR CANADIAN BASE METALS, 1979

Metal	Production (thousand tonnes)		Percent Exported		Percent of Exports to USA	
	All forms	Refined	Refined	Total	Refined	Total
Aluminum	860.3	860.3	64.0	64.0	60.5	60.5
Copper	643.8	397.3	48.1	79.1	37.2	15.6
Lead	315.8	183.8	64.2	85.4	51.9	36.1
Nickel	131.6	75.8	95.3	96.8	71.3	46.6
Zinc	1148.5	580.4	74.0	89.5	61.0	36.8

Sources: Canada, Department of Energy, Mines and Resources, Canadian Minerals Yearbook, 1980, and U.S. Bureau of Mines, Minerals Yearbook, 1979-80.

Note: In principle, the export percentage to the USA can vary as Canadian refiners switch their output between U.S. and European destinations. In 1979, for example, Hudson Bay Mining and Smelting and Texasgulf switched their output from Europe to the USA. Despite this, however, the overall export percentage appears quite stable in copper at least, standing at 37.8 percent in 1950 for refined copper exports to the USA, and 37.2 percent in 1979.

with little power to influence these prices. Even if the share belonging to the USSR were removed from table 2, on the argument that the mineral production of centrally planned countries is not often traded internationally and thus has no influence on world prices, the Canadian market shares of aluminum, copper, and lead in 1979 rise only to 6.8, 9.6, and 10.6 percent, respectively. Only in the case of nickel (23.8 percent), and zinc (22.1 percent), where the U.S. production share is very small, with more than 50 percent of requirements met through imports, has there been a possibility of Canadian influence on world prices. The U.S. primary production shares in table 1 for aluminum, copper, and lead were, respectively, 35.7, 21.5 and 17.6 percent of production in the noncommunist world.⁵

The influence of the USA on world metal markets extends beyond its share of world mine or primary refined production. As the world's largest national metal market, the USA consumes approximately 50 percent of total world primary production of aluminum, copper, and lead, with slightly lower figures for nickel and

zinc.⁶ This huge consumer market also generates a great potential for secondary metal recovery. As table 3 shows, for some metals such as copper, secondary production exceeds primary in the U.S. market. This statistic can be misleading, however, since only copper from old scrap (representing obsolete copper products) is outside the copper fabrication cycle and truly competes with

TABLE 3. U.S. PRIMARY AND SECONDARY NONFERROUS METAL PRODUCTION, CONSUMPTION AND IMPORTS, 1979 (thousand tonnes)

Metal	Production			Consumption ^a	Net Imports ^b	
	Primary	Secondary	% Sec.		Total	Canadian
Aluminum	4558.1	1612.5	26.1	6404.7	277.1	185.8
Copper	1515.4	1552.5	50.6	3298.2	469.8	71.1
Lead	578.2	801.4	58.1	1358.3	196.5	47.0
Nickel	544.2	13.2	29.9	209.5	132.9	80.3
Zinc	472.5	370.0	43.9	1394.3	751.3	268.6

Source: U.S. Bureau of Mines, Minerals Yearbook, 1978-79.

^a Consumption may not equal production plus net imports due to changes in private and government stocks.

^b includes net movements of scrap

primary. In 1979, for example, 604 thousand metric tons of copper from old scrap represented 38.9 percent of total secondary copper and 28.5 percent of total U.S. primary plus old scrap. This was still larger than U.S. copper imports and, at 10 percent of world primary supply (excluding USSR), was quite large enough to affect copper prices.

Scrap and the Canadian Steel and Iron Ore Industries

Canadian mine shipments of iron ore were 60.2 million tonnes in 1979 and 50.8 million tonnes in 1980, with a 1980 value of \$1.7 billion, an amount approximately equal to the value of copper or nickel production.⁷ Canada ranked fifth in world iron ore production in 1979, behind the USSR, Brazil, Australia, the United States, and China, as shown in table 4. As in nonferrous metals, most production is exported: 81.2 percent of production in 1979.⁸ The ferrous metal industry is, however, like copper and unlike nickel in that there is significant domestic consumption of iron ore. Some of this ore is imported by the Canadian steel industry from U.S. mines while simultaneously Canadian ore is being

exported to U.S. steelmills. This is the result of U.S. ownership of Canadian mines and, at the same time, a degree of equity participation in U.S. mines by Canadian steelmakers who have found it cheaper to participate in Minnesota

TABLE 4. WORLD IRON ORE PRODUCTION, 1978-79
(thousand tonnes)

Country	1978		1979	
	Production	Percent Share	Production	Percent Share
USSR	240,800	28.4	244,000	27.6
Brazil	85,000	10.0	87,000	9.9
Australia	83,189	9.8	85,000	9.6
United States	82,784	9.8	85,000	9.6
China	70,000	8.3	70,000	7.9
Canada	55,400	6.5	60,200	6.8
World	847,772	100.0	883,000	100.0

Source: C.J. Cajka, 'Iron Ore' in Canadian Minerals Yearbook, 1979 (Ottawa: Department of Energy, Mines and Resources, 1981).

mining operations than to develop whole new iron mining complexes in Canada. The iron ore imports in 1979 amounted to 5.9 million tonnes or 9.8 percent of ore production in that year.⁹ The industry is regional in nature - like nickel, and significantly more than copper - with 99 percent of shipments from either Ontario or from the Labrador Trough region of Quebec-Labrador.

Exports of iron ore have traditionally gone to the United States because of both transport cost advantages and U.S. equity participation in Canadian mines. The share exported to the USA has been falling in recent years, however, due to the low capacity utilization in U.S. steelmills, resulting from high costs in that country, particularly relative to Japanese mills. Currently, only about half of Canadian exports now go to the USA, despite the high degree of U.S. ownership, with the remainder mainly going to western Europe (35 percent) and Japan (11 percent). As discussed further in chapter 3, the exports to the USA are in the form of pellets, a product superior to direct shipped ore, while ore shipped to Japan is largely in concentrate form.

As in copper and other metals, the exports to the USA (22.8 million tonnes in 1979) represent only a fraction of U.S. production and consumption of ore. U.S. ore production is 3.75 times greater than Canadian ore exports, while the latter comprised 18.2 percent of U.S. iron ore consumption in 1979. Canada is

thus in the position of price taker even within the limited North American market, which for iron ore is somewhat insulated from world ore trade. Although Canada supplies two-thirds of U.S. iron ore imports, there is also competition from Brazil and Venezuela, which together export about 7 or 8 million tonnes to that market.

Ferrous scrap in the U.S. competes indirectly with iron ore by substituting for pig iron in steel furnaces. This pig iron is produced in steel company blast furnaces. In 1979, the consumption of 127.5 million tonnes of iron ore resulted in production of 78.9 million tonnes of pig iron, which was consumed in steel furnaces along with 89.7 million tonnes of ferrous scrap. Because iron ore is only about 65 percent iron, a tonne of scrap thus substitutes for about 1.5 tonnes of iron ore. In terms of iron ore equivalence, steel scrap in the U.S. market has over 6 times the importance in U.S. steelmaking than the approximately 23 million tonnes of Canadian iron ore exports. The magnitudes of U.S. iron ore production, consumption, and imports are shown in table 5.

TABLE 5. U.S. IRON ORE PRODUCTION, CONSUMPTION AND IMPORTS, 1975-79
(thousand tonnes)

Year	Production	Consumption			Imports	
		Pig Iron	Scrap	Iron Ore	Canadian	Total
1975	80,153	72,267	74,710	114,126	19,423	47,507
1976	80,556	78,988	81,588	125,424	25,370	45,115
1977	56,865	77,413	83,667	116,034	25,696	38,524
1978	82,916	80,236	90,040	126,835	19,550	34,165
1979	87,116	79,363	89,747	127,480	22,971	34,328

Source: U.S. Bureau of Mines, Minerals Yearbooks.

Note: Iron ore statistics are usually reported in long tons of 2240 lb. These have been converted to metric tonnes of 2204 lb. for consistency.

The Consequences of Increased Scrap Use for Canada

The great interest on the part of the USA and other countries in encouraging secondary rather than primary resource use derives from several sources. Initial concern on the part of some about the physical depletion of primary metal deposits, engendered by early research such as the alarmist Meadows and Meadows study, Limits to Growth, in the early 1970s, has given way to more rational concern about the secular decline in the grades of many minerals. For example, the average yield of copper ore mined in the USA declined from .89 percent in 1950 to .49 percent in 1979.¹⁰ This phenomenon has not been confined to

the United States. In Canada, average iron ore grade fell from 62 percent to 42 percent from 1961 to 1976, and the average grade of all base metals (nonferrous) went from 3.1 percent to 1.6 percent in the same period.¹¹ The mining industry as a whole has apparently just managed to control the effects of declining grades by means of technical advances which have increased labour and capital productivity.¹² However, the increased beneficiation required for lower grade ore requires a great deal of energy, particularly from scarce fossil fuels such as heavy fuel oil. The escalating cost of this energy is beginning to make scrap metal a very competitive alternative, as it has been estimated that reclaiming metal from scrap is as little as 1/25th to 1/10th as energy intensive as the production of virgin metal.¹³

The other major problem with primary as opposed to secondary metal recovery concerns the generation of pollutants. While the reclaiming of scrap to usable purity often requires a smelting and/or refining process, which of course pollutes, secondary recovery does not produce the quantities of sulphur dioxide emissions that have been the byproduct of the smelting of sulphide ores. It has been estimated that 2.5 to 3 million tonnes of sulphur dioxide pollutants are emitted each year by nonferrous smelters in the USA, and about the same in Canada. This represents about half the total Canadian emissions, and about 1/10th of those in the USA where most pollution is from thermal power stations.¹⁴ As we shall discuss in detail in a later chapter, environmental concerns resulted throughout the 1970s in increasingly stringent controls on primary smelters that have significantly increased the costs of processing primary ores. At the same time, environmentalists, abetted by the National Association of Recycling Industries, have pushed hard for the subsidization of secondary recovery and in 1981 succeeded in forcing the removal of what they considered to be discriminatory rate practices on the part of railroads against scrap and in favour of primary metal.

From a global or even a U.S. perspective, the arguments in favour of increased recycling are compelling. There is no question that encouragement of increased scrap use will conserve both energy and nonrenewable non-fuel minerals. In Canada, however, although scrap generation is maximized, its generation is limited by a consumer market that is small relative to the domestic mining industry.

The major Canadian scrap markets are centred in the eastern industrial heartland, especially in the Toronto-Hamilton area,¹⁵ but dealers' receipts of copper, lead, and zinc scrap in Canada in 1978 were only 150,003, 51,497, and 8,942 tonnes: respectively, 23.2 percent, 16 percent, and .8 percent of primary metal production.¹⁶ The Canadian steel industry uses a considerable amount of scrap as well as iron ore, as we have seen (9.3 million tonnes in 1978), but the generation of this amount of scrap represents only 15-20 percent of the iron ore

tonnage produced in Canada.¹⁷ This contrasts with 97.5 million tonnes of scrap produced in the United States in that year as opposed to 66.3 million tonnes of iron ore, a scrap generation ratio of 147 percent.

Increased recycling in Canada would, of course, be beneficial, but it is not clear whether greater use of scrap abroad is unambiguously in the national interest. Subsidization of U.S. scrap production will lower scrap prices, and, by inducing some substitution of scrap for primary metal, put downward pressure on the primary metal price. Because of the much larger production than consumption of primary metal in Canada, our national interest generally lies in high copper prices - the cost to consumers being more than outweighed by the gains to producers. As we shall discuss in a later chapter with reference to copper, the effect of this is, however, not likely to be large.

The effects of increased U.S. ferrous scrap generation on Canada are less easy to ascertain. Since the Canadian steel industry is a large scrap consumer, a fall in scrap prices would be to its benefit; for a small change in price the reduction in its cost would be approximately $D_s \Delta P_s$, where D_s and P_s represent domestic scrap demand and price, respectively. However, the price reduction would hurt scrap dealers by the amount $S_s \Delta P_s$, where S_s represents supply. Since Canada's external scrap trade is approximately balanced (with $D_s=S_s$), from the national point of view the two effects would cancel out, there being only a domestic income transfer from producers to consumers of scrap.¹⁸

There remain the effects on the Canadian iron ore industry. As noted, more than 75 percent of the domestic iron ore industry is owned by U.S. steel producers, although Canadian steelmakers also own U.S. mines and import U.S. ore. Increased ferrous scrap generation has a long-term potential of substitution for both Canadian and U.S. ore, although, as we shall see, this effect is likely to be slight in the short term, because of the structure of the North American iron ore market. This longer-term relative reduction in iron ore demand is not likely to greatly affect Lake Erie base prices, which are not market determined, so the ore-importing Canadian steel industry is not likely to benefit. Because of the largely foreign-owned nature of the iron ore industry, the potential income loss to Canada due to reduced export demand would not be $P_o \Delta D_o$, where ΔD_o represents the reduction in demand for ore, but only about 25 percent of this, plus the loss of wage income and government taxation revenues in the foreign-owned sector.

The actual magnitudes of the costs and benefits of increased recycling for the Canadian mining and steel industries depend on the empirical relationships between primary and secondary metal in the North American metal industries. The following chapters attempt to quantify these relationships for copper and ferrous scrap, ultimately by building economic models of these industries.

3. THE STRUCTURE OF PRIMARY AND SECONDARY COPPER AND FERROUS METAL MARKETS

Introduction

The scrap market is an integral part of metal markets such as copper or steel, comprising nearly 50 percent of total metallics in such industries, as outlined in chapter 2. This chapter will outline in more detail the relationship of scrap with virgin metallics in these markets. Our discussion includes the nature of scrap dealer operations, the flow of the different types of scrap within the industries, and the relationships of the different market participants, with a view to setting the stage for the economic models of scrap and primary interaction discussed in the following and subsequent chapters.

Description of Scrap Dealer Operations

The North American scrap metal industry has a two-tiered structure, with (a), a large number of small scrap collector-dealers, who also perform a limited amount of processing, selling scrap to (b), the second tier, the larger commercial dealers, who have more sophisticated machinery. The collector or small dealer usually employs simple hand-sorting methods to segregate recognizably different metals or grades and to bale material for easier shipping. Even this limited processing requires at least one crane, a baler, and several trucks, averaging a total capital cost in 1980 prices of \$750,000.¹⁹ There has been a significant trend in recent years toward increasing capital intensity and, consequently, of centralizing even the smaller dealers' operations. An example of this is the disappearance, at the bottom of the hierarchy, of the itinerant junk collector who went from plant to plant and from household to household. This collection function has largely been acquired by municipalities and by ongoing collection systems installed in plants under contract to the small dealer. Until recently, little metal scrap has been recovered from household refuse because of the very low quality of such scrap (the high proportion of paper, for example), coupled with environmental controls on burning as a segregation method. Great interest is now being taken in this problem in parts of the USA, however, and increased recovery rates for aluminum cans have been achieved by means of deposit return policies. This is a very large potential source of scrap.

The commercial dealers generally confine their activities to cleaner and more concentrated sources of scrap. A major source is prompt or new scrap from metal fabricating plants, which takes the form of turnings, borings, and the like and is relatively easy to segregate because it is relatively clean (except for oil and grease contaminants) and of known quality. This is because the product

fabricator is usually able to keep new scrap sufficiently free of impurities and also knows what additional metallic substances are alloyed with the principal metal being sought from the scrap. In many cases new scrap can be recycled directly to the company from which the metal was purchased (if it is clean and of high quality) because the metal foundry or alloy producer knows the composition of the product it has sold. In this case the dealer is simply doing, under contract, what the fabricator usually does for himself in the recycling of return scrap, which does not appear on a market. In general, the fabricator retains title to the scrap because it is an integral part of his copper supply and he wants it back; the scrap dealer simply performs a contracted sorting and processing service. New scrap is the most desirable form of purchased scrap (undergoing a market transaction) because of the regularity and dependability of its generation, its known quality and content, and its concentration of supply.

New scrap material is processed by dealers rather than by the fabricators themselves because of a certain amount of scale economies in the use of specialized processing equipment. The prompt material thus is fed to the dealer automatically, as it is generated, although after processing the dealers can hold it off the market for purposes of speculation.

Even though of generally high quality, there are differences in grade even within new scrap. In copper, for example, the top scrap grade is brass mill scrap, which is effectively indistinguishable from primary copper, and consists of material such as rods and clean unalloyed heavy wire. These do not require refining but go straight back into melting pots at brass mills and ingot makers. Most other new scrap is number 1 scrap, slightly less pure than brass mill grade and consisting of wire, tubing, or copper sheet. This can be sent directly to a wirebar furnace without electrolytic refining. Of course, scrap material does not have to be pure copper to be recycled but can be alloyed material of known composition, if it is to be reused in alloy forms. Important copper alloys are commercial bronze, red brass, low brass, and yellow brass, containing 10 percent, 15 percent, 20 percent, and 35 percent zinc respectively. There are also many leaded brasses as well as bronze alloys (containing tin).

The third scrap type, obsolete scrap, is generated as a result of wear, damage, technical obsolescence, or disappearance of a market for previously manufactured products. Since obsolete scrap is generated from numerous products, it may be alloyed or otherwise combined with any number of metallic or nonmetallic materials that may or may not be of recognizable composition. The recovery of obsolete scrap, therefore, can vary from the relatively simple recovery of lead from batteries or steel from demolition (demolished ships, buildings, bridges)

to the more complex process involved in recovering scrap steel from such articles as junked automobiles. Although obsolete scrap can be number 1 grade copper, for example, most obsolete material contains more impurities than new scrap and thus is number 2 or below, and must undergo refining before reentry into the copper market. The lowest grade of recoverable copper scrap is called smelter grade, and consists of scrap such as furnace bottoms, generator armatures, ashes, pickle and other residues, oxidized scale, and other contaminated material. Smelter grades are distinguished by the necessity to be smelted in a reverberatory or blast furnace and converter (producing blister or black copper) in addition to refining.

The automobile as a source of both ferrous and nonferrous scrap has a unique position in the scrap recovery cycle in that the automobile is initially stripped, not by scrap dealers for its scrap metal value, but by auto wreckers who are interested solely in the used auto parts. Since the auto wreckers sell the stripped hulks to scrap dealers, they effectively perform the scavenging function of the dealers as well as assuming the considerable costs of dismantling the removable parts.

When the stripped auto body arrives at the scrap dealer's, the dealer removes the radiator for its copper, and may remove other items containing nonferrous metals, such as zinc in die cast parts and the motor block if it is aluminum. The body is then flattened for transport to a larger dealer, along with the sorted bales or bundles of new scrap and other old scrap from heavy durable goods, such as refrigerators and stoves.

The major dealers are at the centre of the scrap industry and perform several essential functions. There are over a dozen of these large dealers in Canada in the Toronto-Hamilton area and more than 100 in the United States. These dealers act as brokers for the industry, receiving most of the orders for purchased scrap from the major scrap customers and distributing them among processors for shipment. Branner²⁰ gives the best description of the relationship of the scrap broker with the smaller dealers:

The collector of old scrap sells to a dealer and receives cash on delivery at the going rate.... The dealer, who sorts and processes the scrap, then attempts to sell to either a broker or a consumer. The dealer, paying cash for his scrap, must be adequately financed, because his cash payments to collectors may run to several thousand dollars a day. By selling through a broker the dealer's cash position is supported.

When a broker purchases scrap from a dealer he takes title to the scrap at the yard loading point, paying the dealer 75-90 percent of the loading price. After the scrap has been delivered to and checked by a consumer as to weight and grade, which usually requires about 30 days, the customer

makes an adjusted payment to the broker who then pays the dealer the remainder. Brokers to a considerable degree support the dealer's cash position.

Besides being brokers, the large dealers are also the major processors, having invested in large balers, shredders, and magnetic separation equipment. The balers hydraulically compress complete auto bodies, refrigerators, and stoves into compact bundles of the necessary size and density for charging into the steelmaking furnaces. Number 2 heavy melting steel scrap, for example, must be not more than 5 feet by 18 inches and made up of steel at least one quarter inch thick to give the density for proper melting. Other scrap grades are the number 1 and number 2 bundles, which are new scrap (high grade) and automotive sheet steel (lower grade) respectively, compressed into packages weighing at least 75 pounds per cubic foot. Auto bodies that have not been shredded are sold as number 2 bundles for a relatively low price, since the nonferrous metal contaminants have not been effectively removed. Copper, tin, zinc, and other nonferrous metals are contaminants in steelmaking because they interfere with the melt or collect in the cleaners. Iron and steel scrap specifications (for number 2 bundles) limit total nonferrous metals to .6 percent by weight, with copper not exceeding .1 percent. The specifications are more stringent for higher grades. Since even the contact points in automobile dashboard instruments, etc. may have an effect on the nonferrous specification, there is a major incentive to try to remove these various contaminants. That is the role of the auto shredder, which has caused a major revolution in scrap processing in the last decade.

The shredder or fragmentizer is basically a very heavy-duty hammermill that converts automobile hulks and other large scrap sources into fist-sized pieces from which nonferrous metals and nonmetallic waste can be separated easily. The shredding plant usually includes a system for blowing away nonmetallics, a magnetic separator for segregation of nonferrous metals, and sometimes a smelting furnace for recovery of the nonferrous components. A flow chart of a typical shredder is shown in figure 1.

A large shredder can handle two auto hulks per minute. The first of the large auto body shredders was installed in 1958 in Houston by Proler Steel to prepare scrap for their electric steel furnace in that area. Expansion of the technique took place slowly throughout the sixties until currently there are about 160 shredding plants in the USA with a capacity of over 5 million net tons of product annually.²¹ There are also 12 shredders in Canada, most in the Toronto-Hamilton area. Shredders are expensive, ranging in price from \$1 million to \$3 million, but they considerably improve the profit margin of the dealer. Since a dealer must have sales of at least \$750,000 a year in order to use one efficiently, they have hastened the tendency for control of the scrap industry to concentrate in the large dealer-brokers.

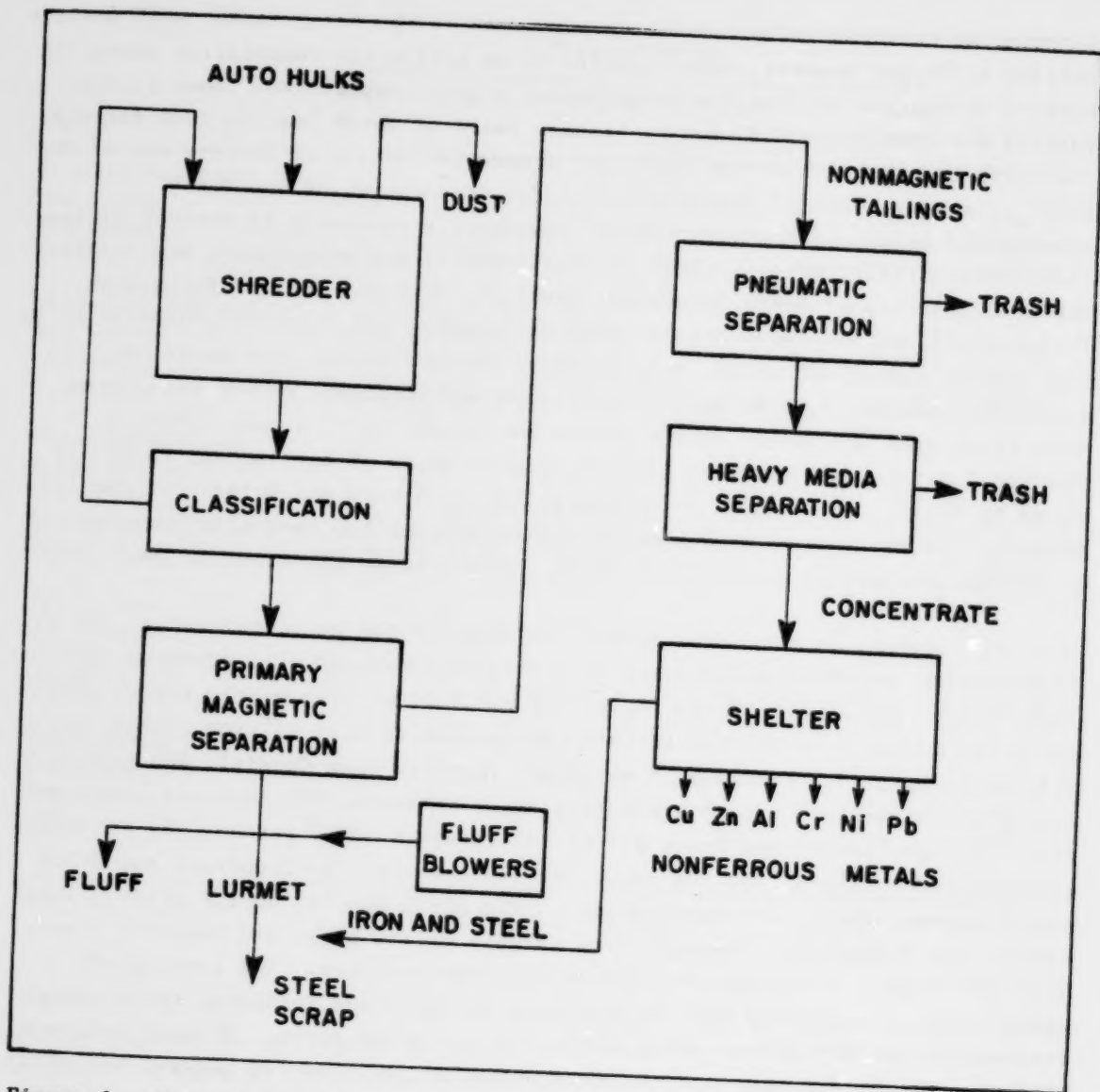


Figure 1. Flow chart of shredding plant

The Structure of the Primary and Secondary Copper Markets

Despite the existence of a two-tiered structure in the scrap market with dealers selling to larger brokers, there appears to be sufficient competition among the brokers themselves to keep the scrap market highly competitive. Some of the largest and best known U.S. dealer-brokers (most of which deal in both ferrous and nonferrous metals) are as follows: Commercial Metals of Dallas, one of the world's largest, with 12 subsidiaries; Ogden Corporation of New York; Diversified Metals of Missouri (which, however, is reputedly in current financial difficulties); Metallurgical International of New Shrewsbury, New Jersey; Roblin Industries of North Tonawanda, New York; Steelmet Inc. of Pittsburgh; Proler Steel and Federated Metals, both of Houston; and Whittaker Corporation of Los Angeles, among others.²² Many of these dealers either have their own specialty steelmills, like Roblin Industries and Steelmet, or are associated with integrated steelmills or the larger nonferrous smelters and refiners. Federated Metals, for example, (like Federated Genco of Burlington) is wholly owned by Asarco, the largest secondary refiner. Stelco and Dofasco of Hamilton, Ontario, the two largest Canadian integrated steelmills, have also recently purchased Intermetco, a U.S. scrap dealer with a large operation in Hamilton.²³

The large brokers in turn have several outlets for the processed scrap, the main buyers being secondary and primary refiners, producers of mill products, and ingot makers (producers of castings). Of the 2.07 million metric tonnes of copper scrap consumed in the USA in 1979 (as opposed to 2.16 million tonnes of refined copper, 63.8 thousand of which was imported from Canada), 486 thousand tonnes (23.4 percent) was consumed by primary refiners, 703 thousand (33.9 percent) by ingot makers and brass mills, 795 thousand (38.4 percent) by secondary smelters and refiners, and the remainder (4.3 percent) by foundries and other miscellaneous users. The destination of the scrap depends on its grade. Ingot makers' and brass mill consumption is largely yellow brass and number 1 copper, both new scrap. Foundries also use mainly number 1 wire. The lower-grade obsolete scrap generally goes to secondary smelters and refiners, their largest consumption in 1979 being number 2 wire and low grade scrap. Primary refiners consume both new and old scrap in about equal proportions (60 percent old scrap in 1979) consisting almost entirely of number 1 and number 2 wire. Table 6 illustrates the different proportions. In total, 61 percent of scrap supply in 1979 was new scrap.

TABLE 6. CONSUMPTION OF U.S. PURCHASED COPPER SCRAP, 1979
(1000 tonnes)

Customer	Type of Scrap					Total
	No.1 Wire	No.2 Wire	Yellow Brass	Auto Radiators	Low Grade	
Primary Refiners:						
New scrap	43.4	93.4			57.2	194.1
Old scrap	57.5	62.6			166.0	291.9
Total	100.9	156.0			223.2	486.0
Secondary Refiners:						
New scrap	6.0	115.4	5.7		203.8	349.8
Old scrap	53.5	115.0	41.3	84.9	73.8	445.3
Total	59.5	230.5	47.0	84.9	277.6	795.2
Ingot Makers and Brass Mills:						
New scrap	164.8	49.3	295.8			
Old scrap	30.1	1.4				671.6
Total	194.9	50.6	295.8			31.5
						703.1
Foundries:						
New scrap	11.2	5.3	6.4			
Old scrap	25.5	4.7	4.7	9.1		27.3
Total	36.7	10.0	11.1	9.1		61.4
						88.8
Total Scrap Use:						
New scrap	225.4	263.4	308.0		261.1	1242.9
Old scrap	166.0	183.8	46.0	94.1	245.6	830.3
Total	392.1	447.3	354.0	94.1	506.7	2073.2

Source: U.S. Bureau of Mines, Minerals Yearbook, 1979, vol. 1, p. 291.

The extent to which copper scrap actually substitutes for primary copper in the market depends on the degree of processing necessary and on the extent of competition between the scrap consumers, (competition preventing them from restricting purchases to hold down buying prices), and among the scrap dealers themselves. As consumers, ingot makers are the most competitive and, as they use scrap of virtually primary quality, they are largely indifferent to the use of either scrap or refined copper. In fact, most of their scrap use is their own product, recycled and simply remelted into the proper alloy for the brass or bronze casting that they manufacture (plumbing fittings, for example). According to statistics from the U.S. Census of Manufacturers, including foundries there were 490 such companies in 1972, with the top 4 firms accounting for only 20 percent of the sales, a relatively unconcentrated industry. The

brass mill industry (making copper and brass tubing), while having similar scrap needs as ingot makers (and included with them in table 6), may be somewhat more concentrated, as major primary and secondary refiners tend to own their own brass mills. Chase Copper and Brass, one of the largest, is owned by Kennecott Copper, for example, while Anaconda, Cerro Corporation and Asarco own respectively Anaconda American Brass, Cerro Copper and Brass, and Revere Copper and Brass.

While ingot makers and brass mills consume the majority of new scrap (and more new scrap than copper: 672 thousand versus 610 thousand tonnes in 1979) the real addition to the copper supply results from old scrap collection, new scrap being essentially inventory or work in process. Because as a rule old scrap tends to be of lower grade, it must undergo further processing before reappearing as refined copper; this smelting and refining is done by both the primary copper producers and by specialized secondary refiners. This secondary refining industry is dominated by three large firms, The American Smelting and Refining Company (Asarco), American Metal Climax (Amax), and Phelps Dodge Refining, the three of which in combination control about one third of the secondary refinery capacity as well as some primary refining capacity (Asarco is the largest U.S. custom refiner), and have at least a potential influence on the price paid for scrap. Like secondary refining, primary copper refining operates in a market that is essentially oligopolistic in structure. The core of the primary copper industry throughout the 1960s was composed of eight major firms: three U.S. - Anaconda, Kennecott Copper, and Phelps Dodge; two Canadian - Inco and Noranda Mines; and the remainder African producers - The Anglo American Corporation (AAC), Roan Selection Trust (RST) in Zambia, and Union Minière du Haut Katanga, in what is now Zaire.²⁴ These major producers controlled between 55 and 75 percent of the world market for refined copper (including secondary refining). The remaining market share was held by fifteen smaller producers and about 25 custom refiners (of which Asarco is the largest, refining both mine copper and scrap). If the U.S. market is considered separately, the six largest domestic firms (the three mentioned above plus Asarco, Amax and Newmont Mining) accounted for nearly 90 percent of U.S. refining capacity in 1974.

Although tariffs and transport costs are low for copper, giving it a world market, the copper market is segmented geographically to some extent by traditional sales areas on the part of the major producers, at times enforced by U.S. export quotas. This was certainly true during periods when the two-price system operated, in 1954-56 and 1964-70, when the U.S. producer price was different from the price on the free copper market represented by the London Metal Exchange (LME) and by the related merchant New York Commodities Exchange (COMEX).²⁵ However, since May 1976, when Kennecott introduced a major change in its pricing system by setting its price for copper, the copper market has become

much closer to the textbook free market. This has also meant a real world market, because the export controls required to maintain the two-price system became redundant.

The major Canadian producers, especially Noranda,²⁶ tend of necessity to sell in the U.S. market at prices within one or two cents a pound of those of the major U.S. primary refiners, and sell the remainder of their output either to merchants in the U.S. at a price related to the COMEX price, or in Europe at the prevailing LME price.

Many of the major primary copper producers are integrated forward into semifabrication, owning either wire or brass mills. Besides the brass mill subsidiaries previously noted, Anaconda, Phelps Dodge, Noranda, and Asarco all own wire mills that use their own refined copper wirebar. It has been estimated that about one-third of U.S. copper refinery output is sold to downstream affiliates. The extent of vertical integration is increasing as well, as the result of a recent process for the continuous casting of copper directly from cathodes into the desired shapes at the refinery. This makes obsolete the independent fabricators who formerly purchased cathodes from the refiner and cast the semi-manufactured shapes. The effect of vertical integration is to subtract from the real market the part of producer's output sold to their captive customers, making the real market thinner and giving each remaining producer a larger real market share.

Despite concentration among primary and secondary refiners and the fairly high degree of vertical integration, the overall U.S. scrap market probably remains fairly competitive, especially for the higher scrap grades. On the supply side, there are large numbers of dealers and even dealer-brokers, with none large enough to control the price. On the demand side, an important factor limiting the ability of primary or secondary refiners to control the purchase price is the existence of international trade in scrap as well as refined copper. In 1979 the U.S. exported 171,000 metric tonnes of alloyed and unalloyed copper scrap and imported 23,000 tonnes, respectively 11 percent and 1 percent of total secondary production.²⁷

The Structure of Steel, Iron Ore, and Ferrous Scrap Markets

Steel manufacturing is more dependent on scrap than any other sector of the mineral industry, consuming 89.7 million metric tonnes in 1979 compared with 79.4 million tonnes of pig iron: a scrap/pig-iron ratio of 113 percent.²⁸

On this basis, one could describe the steel industry as a direct scrap processing industry, since ferrous scrap is charged directly into steel furnaces, with no intermediate smelting or refining as with nonferrous scrap. The main reason for high scrap use in steel is that the huge volume of home and purchased scrap generated allows it to be priced competitively with pig iron.

Unlike other primary metals, steel is not produced directly from ore, but from another metal, pig iron, and from scrap. Pig iron is produced in a blast furnace using iron ore, limestone (flux) and coke, a distillation of coal. Thus the steel industry is really not a primary metal industry, but is the second stage of a two-stage process in which pig iron is the primary metal. However, the largest steelmaking facilities integrate both the blast and steel furnaces in a sequential operation, the pig iron being immediately charged hot into the steelmaking furnace. It is obvious that an energy saving results from the proximity of the two furnaces, obviating the necessity for reheating the iron. The raw steel produced in the furnace is then cast into ingots which undergo finishing. The principal finishing process is rolling, which is usually divided into two stages. The ingots are first rolled by semi-finishing mills into 'slabs' (with an oblong cross-section), then re-rolled in finishing mills to produce a wide variety of shapes, such as plate, strip, and sheet steel. Ingots destined for shaping into rails, wheels, or other shapes may instead be rolled into 'blooms' (with a square cross-section), and, in the case of wire or bars, further rolled into 'billets' (about 2-4 inches square). The variety of final products is tremendous. Figure 2 is a flow chart of the various steelmaking processes.

There are still three main types of basic steelmaking furnaces in use, although their shares have changed dramatically in the last two and a half decades. The main technical change since the 1950s has involved the replacement of the old open hearth (OH) by the much more efficient basic oxygen furnace (BOF). As the name implies, the BOF employs an injection of pure oxygen to speed the furnace reaction and as a result can produce a heat (a batch) of steel in 45 minutes, instead of 10 hours in the open hearth. When the BOF was introduced, the major U.S. firms were at first reluctant to innovate and in fact Dofasco in Hamilton was the first in North America to utilize the new furnace. The U.S. giants were subsequently forced by Japanese and German competition to follow the lead. The BOF share in the USA rose from 3.3 percent in 1960 to 61.0 percent in 1979 while the OH fell from 87 percent to 14.0 percent in the same period. The remaining 24.9 percent is made up by the electric furnace.²⁹

The rise of the BOF and decline of the open hearth furnace have had major consequences for the degree of scrap utilization. For technical reasons outlined in more detail in chapter 6, the open hearth furnace allows a considerably wider

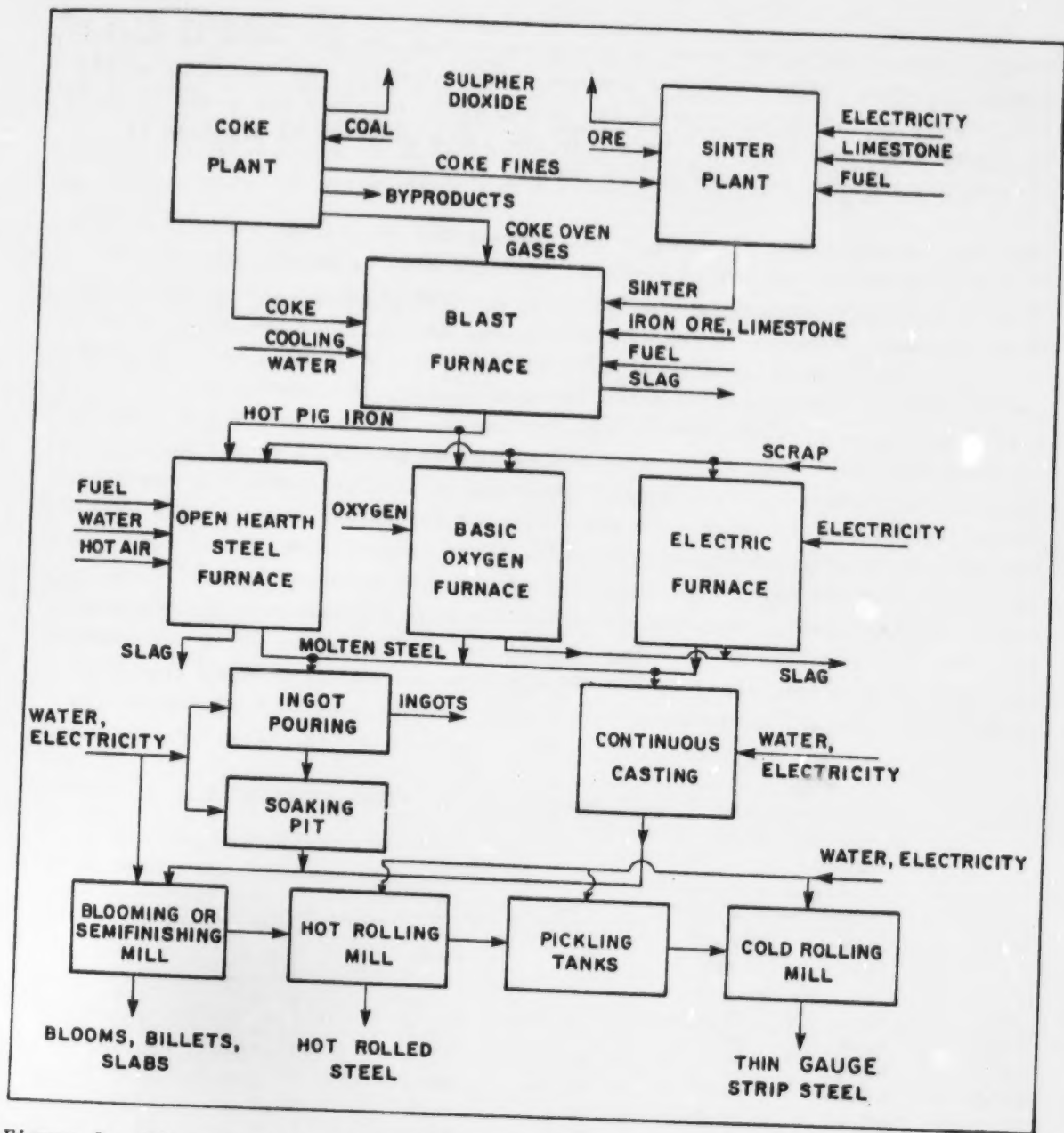


Figure 2. Flow chart of a steel-making process

range of variation in the scrap/pig-iron ratio than the BOF, which is currently limited to about 30 percent as a maximum. Consequently, the expansion of the BOF furnace in carbon steelmaking has tended both to reduce the usage of scrap in recent years and to limit changes in the ratio of scrap to pig iron in response to changes in scrap prices and pig iron costs.

That the overall share of scrap in steelmaking has not fallen since 1950 is due to the increase in the use of electric furnaces simultaneously with the BOF. The electric furnace, unlike the BOF which employs the heat in the hot pig iron, generates heat by means of graphite electrodes arcing above the metal to be melted. Using this external heat source, the electric furnace theoretically can use 100 percent cold metal or scrap (or alternately, 100 percent pig iron). A smaller and more flexible furnace than either the BOF or the old open hearth, it is especially well suited for alloy and stainless steels, although it can produce the full range of steel types, including reinforcing bars from low grade scrap, and in fact is being more and more used for carbon steels. Its expanded use has resulted from a higher demand for these special steels and, more importantly, the now prohibitive capital cost of a new integrated steelmill. A specialized mini-mill can produce reinforcing bars for one-third to one-quarter the cost of production in an integrated mill. Table 7 shows scrap use within furnaces and furnace shares in U.S. steelmaking for selected years from 1956 to 1979.³⁰ The overall scrap share in 1979 was 47.8 percent of total metallics.

TABLE 7. SCRAP USAGE AND FURNACE SHARES IN U.S. STEEL PRODUCTION, BY FURNACE TYPE, 1956-79 (percent)

Year	Open Hearth		Basic Oxygen		Electric	
	Scrap Use	Furnace Share	Scrap Use	Furnace Share	Scrap Use	Furnace Share
1956	46.1	92.2	-	0.0	97.9	7.8
1960	41.8	88.1	28.1	3.3	96.3	8.6
1965	41.6	72.0	29.6	17.5	97.7	10.5
1970	40.9	36.5	29.1	48.2	98.1	15.3
1972	46.4	26.2	28.7	56.0	96.9	17.8
1974	46.0	24.4	28.6	56.0	96.9	19.7
1976	44.3	18.3	28.4	62.4	97.6	19.2
1979	44.9	14.1	27.9	61.1	97.9	24.9

Source: U.S. Bureau of Mines, Minerals Yearbook.

The steel market in the United States is a concentrated fairly tightly-knit oligopoly. Although there are about 200 steel and related companies in total, the 30 integrated producers are the core of the industry and, as table 8 shows, the largest eight of these account for nearly three quarters of the total shipments. U.S. production of about 125 million metric tonnes represents approximately 17 percent of world steel with a value of over \$48 billion in 1978 output.³¹

TABLE 8. STEEL SHIPMENTS OF THE LARGEST U.S. AND CANADIAN COMPANIES

Company	Shipments (million tonnes)	Share Percent
U.S. Producers: (1978)		
U.S. Steel	28.4	22.9
Bethlehem	17.1	13.8
National	9.5	7.7
Republic	9.1	7.3
Inland	7.8	6.3
Armco	7.7	6.2
Jones and Loughlin	6.7	5.4
Youngstown	3.8	3.1
Largest 8 U.S. firms	90.0	72.7
Total U.S.	124.0	100.0
Canadian Producers: (1976)		
Stelco	5.5	
Dofasco	3.2	
Algoma	2.8	
Largest 3 Canadian firms	11.5	78.3
Total Canadian	14.7	100.0

Source: American Metal Market, Metal Statistics.

The degree of concentration in the North American steel market has not promoted competitive pricing behaviour. The largest steel producer, the United States Steel Corporation, is widely regarded as the price leader, despite a declining market share. Although on several occasions its efforts have in fact been frustrated by the refusal of rivals to follow its leadership, even in the face of industry-wide wage bargaining, there has never been anything resembling a real price war in the domestic steel industry, and price is generally not used as a means of competition.³² Most studies in the 1960s found prices to be determined by average costs, irrespective of the volume of imports.³³

This behaviour may be partly explained by the effects of the domestic antitrust laws. An integrated firm such as U.S. Steel producing many steel products may have enough overall profit to be able to lower its price to meet foreign competition on a particular item, such as wire rod, but the result may be to drive non-integrated U.S. producers out of business, an action which would not be appreciated by the Justice Department. The result has been to leave domestic prices high, irrespective of imports, a policy which has been disastrous for the industry in the long run.

From 1960 to 1978, imports of steel products into the USA rose from 3.7 to 21.8 million metric tonnes, an average increase of over 25 percent per year, while exports dwindled to 3 million tonnes in the same period. Imports now represent about 18 percent of U.S. consumption and one-third of total steel trade.³⁴ While world steel production expanded by 153 percent from 1955 to 1979, U.S. production grew only by 9 percent, capacity utilization remained only at about 80 percent, (even before the 1982 recession), and profits have been continually low (for example, 3.6 percent of sales in 1976). These low profits inhibit the necessary investment required to modernize obsolete plants. The unemployment caused by the chronic slump in domestic steel production recently prompted the introduction of higher tariffs on imported (especially Japanese) steel: the so-called 'trigger price' mechanism, whereby a surcharge is imposed whenever imports enter at lower than domestic prices. Such protection removes the offshore threat for the time being, but the general competitive position of the U.S. industry remains weak. These measures, of course, were powerless against the worldwide slump in demand occurring in 1981-82.

The low level of capacity utilization has, of course, reduced the U.S. demand for both scrap and iron ore relative to that of Europe or Japan. The result has been an incentive to increase scrap exports from the USA to Japan, a response strongly objected to by the steel industry because of its effect on scrap prices. Scrap export controls were imposed in 1965-66 and in 1973-74 when scrap prices rose in the face of the unusual steel market boom in that period. As in the copper market, scrap prices fluctuate widely in response to market changes.

The North American market for iron ore, in contrast, is not a competitive but a captive market, as most ore is received from own-company mines.³⁵ These mines are located in Michigan, Wisconsin, and Minnesota in the United States and in Ontario, Newfoundland, and Quebec in Canada. The modern Canadian industry dates from the early 1950s, when U.S. companies began exploiting the reserves of the Labrador Trough following the depletion of Mesabi range reserves. There are currently 15 ore producers in Canada operating 16 mines, the largest of which is the Iron Ore Company with a capacity of 31.5 million tonnes in 1976, followed by

Quebec Cartier Mining with 18.7 million tonnes, and Wabush mines with 6.1 million, all in the Quebec-Labrador region. These firms are 88 percent, 100 percent, and 58 percent U.S. owned, respectively, with the overall U.S. ownership 77 percent.³⁶ The 88-percent foreign ownership of the Iron Ore Company is divided among 7 large U.S. firms, including U.S. Steel which owns Quebec Cartier. Inland Steel and Youngstown Sheet and Tube together have 26 percent of the 58 percent foreign ownership of Wabush Mines; the 42-percent Canadian ownership is divided between Stelco and Dofasco. Algoma Steel produces from a wholly-owned subsidiary in Ontario.³⁷

In response to declining ore grades, and to demands by steelmakers for a higher-quality, more-uniform blast furnace charge, both U.S. and Canadian ore producers began to upgrade the ore by pelletizing, an agglomeration process involving heat. Virtually all Canadian ore shipped to the U.S. is now in the form of pellets, as is ore shipped from the Lake Superior district. Offshore exports, in contrast, are simply concentrated by mechanical means to increase the iron content for transportation. There is now almost no direct-shipped (i.e. unprocessed) ore exported.

The trend toward pelletization and concentration has increased both the captive nature and the energy intensiveness of iron mining. The agglomeration of ore is an exceptionally energy-intensive process, consuming six gallons of heavy fuel oil or 1000 cu. ft. of natural gas per ton of ore.³⁸ Thus pelletizing is undertaken only with an assured market, as in intrafirm sales, and even exports of concentrates tend to be more and more on a long-term contract basis rather than on the open market.

North American iron ore pricing is heavily institutionalized. The basis for intracompany pricing, as well as the small amount of merchant ore traded, is the Lake Erie base price, established by the Hanna Mining Company, a merchant dealer.³⁹ This is really a schedule of different prices for ores of different structure and density, including pellets, delivered to lower lake ports. These classifications are subdivided into Bessemer ore, containing less than .04 percent phosphorous, and non-Bessemer with .045 to .18 percent. Table 9 indicates that Old Range Bessemer is highest in price, followed by Old Range non-Bessemer, Mesabi Bessemer and Mesabi non-Bessemer. Pellets are priced in terms of iron content.

TABLE 9. LAKE ERIE BASE PRICES FOR SELECTED YEARS, 1964-79
(U.S. Dollars per Long Ton)

Year	Mesabi Non-Bessemer	Mesabi Bessemer	Old Range Non-Bessemer	Old Range Bessemer	Pellets
1964-69	10.55	10.70	10.80	10.95	.252
1970	10.80	10.95	11.05	11.20	.266
1973	11.88	12.03	12.13	12.28	.299
1974	15.06	15.04	15.14	15.29	.380
1975	17.89	18.14			.426
1976	19.67	19.88			.515
1977	21.18				.555
1978	22.31				.604
1979	24.56				.678

Sources: C. H. Pye, Profitability in the Canadian Mineral Industry, (Kingston: Centre for Resource Studies, 1981), table 9, p. 60; Energy, Mines and Resources, Canadian Minerals Yearbook, 1978 (Ottawa, 1980), p. 219; and U.S. Bureau of Mines, Minerals Yearbook 1978-79.

Note: In 1973, 1975, and 1976, where prices changed in the middle of the year, the price given is a weighted average. In all other cases the price was effective January 1 and obtained throughout the year. Prices given in long tons of 2240 lb. are equivalent to 1.0163 metric tonnes of 2240 lb. and 1.12 short tons. Pellet prices are per long ton unit (1 percent of a long ton, or 22.4 lb.).

While Lake Erie prices clearly do not represent market clearing prices, there is some indication that they are cost determined, being based on the cost of producing ore from new capacity in the Mesabi Range.⁴⁰ As the value of marginal costs, they are equivalent to prices in a competitive market.

Lake Erie base prices, while important, are not the only determinants of the competitiveness and profitability of Canadian iron ore operations. For a product with such low values relative to weight, transport cost plays a vital role. The total of rail and seaway shipping charges from Sept Iles to Pittsburgh can amount to more than 40 percent of the c.i.f Lake Erie price. Not only does iron ore compete with scrap, but transport charges greatly affect the outcome of the relative locational advantages of Mesabi, Quebec-Labrador, or offshore imported ores. The 1950s and 1960s brought a steady decline in ocean freight rates, resulting from the introduction of larger ocean vessels of 50,000 to 80,000 d.w.t. Combined with lower domestic ore grades, this made Venezuelan ore competitive for eastern North American mills. At the same time, the opening of the St. Lawrence Seaway lowered the Sept Iles-to-Lake Erie tariff from 2.83 per ton in 1959 to 2.20 in 1964,⁴¹ increasing the attractiveness of Canadian ores. The Seaway notwithstanding, the winter freeze, the restrictions on vessel size,

and the absence of return cargoes tend to raise the costs of inland (relative to ocean) ore transport. For a given Lake Erie base price, this obviously lowers the f.o.b value of Canadian ore. Although moderate throughout the 1960s, Seaway transport costs increased rapidly in the 1970s, absorbing the increased Lake Erie prices in table 9 and leaving Canadian prices net of transport cost relatively constant. For example, the tolls for the use of the Seaway increased 13.4 percent from 44.1 cents per tonne in 1977 to 50 cents in 1978, and the rate applied to brass Registered Shipping Tonnage went from 4 to 7 cents per tonne,⁴² as the result of Seaway operation deficits. From 1978 to 1979 freight rates again increased 15 percent to \$4.50 a long ton, excluding tolls.⁴³

Despite increasing shipping and treatment costs, Canadian ore exports to the United States now compete effectively with scrap for two major reasons. First, the limitation on scrap use in the BOF and the need to keep blast furnaces continuously running gives steelmills a preference for ore over scrap, despite growing electric furnace capacity. Second, the ownership of Canadian mines by U.S. steelmills lowers the real cost of ore to these firms. We shall confirm in chapter 6 that the relationship between U.S. pig iron production and Canadian ore exports has been relatively constant over the years, affected only by strikes in Canadian mines, although the relationship between pig iron and scrap use depends to some extent on relative prices.

4. ECONOMIC MODELS OF PRIMARY AND SECONDARY MARKET INTERACTION

Introduction

Scrap or secondary metal acts as a substitute for primary metal derived from ore; hence, it affects both the price and sales of metal from primary producers. To study these effects we will build simplified conceptual models of the copper and steel industries. With these models we can discuss such questions as the relative movements of scrap and primary metal prices in response to changes in general economic activity, the effects of energy price changes on the scrap and primary metal markets, and the extent to which the special characteristics of scrap metal supply contribute to the instability of primary metal prices. In subsequent chapters we will attempt to quantify these qualitative results.

The chapter is in three sections. The first section presents a theoretical copper market model and describes in a general way how the model can be used to discuss the effects of overall changes in demand for durable goods, energy prices, and environmental regulations, as well as market structure changes such as administered copper prices. A similar static model of the ferrous scrap metal is subsequently presented in section two. The third section expands the static models to include both the dynamic effects introduced by special features of the supply of obsolete scrap, and the links between the overall copper and ferrous markets through the scrap market.

A Comparative Static Model of Primary and Secondary Copper

As we have said, the copper and ferrous markets are both of great importance to the Canadian mining industry as a whole, and represent markets with significant scrap market shares. They also are similar in that the United States scrap markets are of major importance for Canadian primary demand. However, because the two industries are quite different, both in general institutional structure and in the relationship of scrap to primary metal, one general model does not suffice. Therefore, we will discuss them in turn.

Scrap in the Copper Market

Although there have been periods of significant producer control of primary prices, the international copper market comes quite close to an idealized free market. Such a free market would be competitive in the sense that no one

producer or group of producers would have the ability to control the price of output or of production inputs through horizontal integration in primary production or through vertical integration into copper fabricating or secondary smelting.

The copper scrap market, like that for ferrous metal, comprises many types and grades of scrap. Its simplifying feature relates to the fact that the consumption by ingot makers and brass mills tends to be new scrap composed of relatively high grade number 1 wire and yellow brass, while the consumption by secondary and primary refiners tends to be old scrap, which is more likely to be lower grade material. This is not quite true, as shown by the amount of lower-grade new scrap going to secondary refiners in table 6, but as a rule new scrap competes indirectly with primary refined copper through its substitution by ingot makers and brass mills, while obsolete scrap competes directly after processing by secondary smelters. Because the supplies of prompt and of obsolete material arise in very different ways, the relationships of the new and obsolete material to the primary market will be different.⁴⁴ How the markets interact will be illustrated in the economic model that follows.

Suppose the demand for refined or finished copper is represented by D_f . This is the demand by all copper users, including wire mills, other copper fabricators, ingot makers, brass mills and foundries. It is, of course, an intermediate and not a final demand and will depend largely on: the price of finished copper, P_f ; an index of durable goods production and/or construction activity which we shall label DUR ; and, because ingot makers and brass mills can substitute prompt scrap for refined copper, on the number 1 scrap price, P_{s1} . Functionally, this is represented by $D_f = D_f(DUR, P_f, P_{s1})$ with demand positively related to DUR and P_{s1} and negatively to P_f .⁴⁵ Total refined metal supply comes from both primary refinery output and secondary refiners. Although secondary refiners process some new scrap and primary refiners some old scrap material, for simplicity we shall represent all old scrap as being processed by secondary refiners to primary quality, in direct competition with the output of primary refineries which use only virgin copper.

Thus, total finished copper supply is the sum of copper from primary and secondary sources respectively, or $S_p(P_f) + S_s(P_f, P_{s2})$. As before, the brackets denote a functional relation. If all suppliers are assumed competitive in simply reacting to market prices, both primary and secondary supply should be positively related to P_f . Because the secondary processors use number 2 scrap as an input, however, an increase in its price with P_f given will reduce the dealer profit margin and tend to reduce current supply. The refined copper market will be in equilibrium when P_f is such that D_f equals total supply.

Since brass mills use new scrap in parallel with refined copper, new scrap demand is of the same functional form as refined copper demand. Like home or revert material, the supply of new scrap arises from waste in copper fabricating and thus would be expected to be simply proportional to total copper demand, D_f . Thus Ps_1 changes to make Ds_1 (DUR, Pf, Ps_1) equal $Ss_1(D_f)$ with D_f itself a function similar to Ds_1 . We shall see that this similarity in form of both the demand and the supply of new scrap can lead to market instability.

The market for old scrap is not between dealers and brass mills, but primarily between dealers and secondary refiners. Old scrap is a derived demand arising from the assumption that secondary processors purchase scrap at given prices for both copper and scrap up to the point when processing profits are maximized. The transformation of scrap into final secondary ingot can be represented, as is usual in economics, by a technical relationship called a production function that shows processed output as a function of labour, capital, energy, and the input of scrap in each time period:

$$Ss = F(L, K, E, Ds_2)$$

Total sales revenue to the processor, assuming all production is sold, is Ss times P_f . Total short run costs are fixed capital costs (or iK where i is an interest rate), and variable labour, energy, and scrap purchasing costs. If w represents the wage for labour hired and P_e the energy price, the processor's costs are:

$$Cs = iK + wL + Ps_2 Ds_2 + P_e E$$

with Ds_2 the purchases of number 2 copper. Short-run profit is revenue less total cost⁴⁶ or:

$$\text{Profit} = P_f Ss(L, K, E, Ds_2) - iK - wL - Ps_2 Ds_2 - P_e E$$

If each dealer maximizes his profit by varying L and Ds_2 with a given wage rate, scrap price, and copper price, he will hire labour, use energy, and purchase scrap up to the point where the value of an additional unit of each equals its cost or:

$$P_f dSs/dL = w; P_f dSs/dE = P_e; \text{ and } P_f dSs/dDs_2 = Ps_2$$

If these 'marginal products' were constant, this would simply mean attempting to operate at full capacity, but in general the efficiency of labour and energy use begins to decline and processing losses begin to increase before capacity is reached. The diminishing marginal product for the purchased scrap input creates

a downward sloping demand curve for old scrap with P_f , w , and P_e held constant. Thus $Ds_1 = Ds_2(Ps_2, P_f, P_e, w)$ with scrap demand negatively related to Ps_2 , P_e and w and positively related to P_f , since an increased copper price will increase the processor profit margin for a given scrap price.

The supply of old scrap from dealers depends positively on the scrap price for the same reason that processors' supply is related to the price of copper. However, because dealers collect from the stock of obsolete copper products, the dealer scrap supply also depends on the size of this stock, $A(t)$. The depletion of this stock by the collection process will introduce dynamic effects into the workings of the scrap market that we shall investigate shortly. At the moment we shall treat A as an exogenous variable in the current period and represent the old scrap supply functionally as $Ss_2 = Ss_2(Ps_2, A)$. As before, Ps_2 will be determined where $Ds_2 = Ss_2$ in the old scrap market.

This completes the specifications for our three-market copper scrap model, which can be summarized by the following three equilibrium relations for refined copper, new scrap, and old scrap, respectively:

$$Df(DUR, P_f, Ps_1) = Sp(P_f, w, P_e) + Ss(P_f, Ps_2, w, P_e) \quad (5)$$

$$Ds_1(DUR, Ps_1, P_f) = Ss_1(Df(DUR, P_f, Ps_1)) \quad (6)$$

$$Ds_2(Ps_2, P_f, w, P_e) = Ss_2(Ps_2, A) \quad (7)$$

The endogenous price variables P_f , Ps_1 , and Ps_2 are determined simultaneously in the model as functions of the exogenous variables DUR , w , P_e , and A . While the algebraic relationships are fairly complex (see appendix I) we shall illustrate two interesting results graphically: the respective effects of a boom (an increase in DUR), and a change in the price of energy, P_e .

The Effects of Economic Expansion on Primary and Secondary Markets

If the other variables are temporarily held fixed, the determination of each price in equations (5) to (7) can be shown graphically by the intersection of the demand and supply curves for copper, new scrap, and old scrap, respectively. Because new scrap and copper are substitutes in brass mill demand, a change in Ps_1 will shift the demand curve for refined copper, as will AP_f change new scrap demand. The final equilibrium occurs when all these interactions have worked themselves out.

To illustrate, suppose there is an increase in U.S. industrial durable goods production (DUR). Because this is an argument of D_f and D_{s1} , both demand curves shift to the right in figure 3, increasing both P_f and P_{s1} along the supply curves for copper and new scrap. The supply of secondary refined copper is usually more responsive to increases in copper price than is primary mine supply, at least up to capacity, meaning that scrap both dampens copper prices by its presence in the market and moderates the price increase when demand increases.

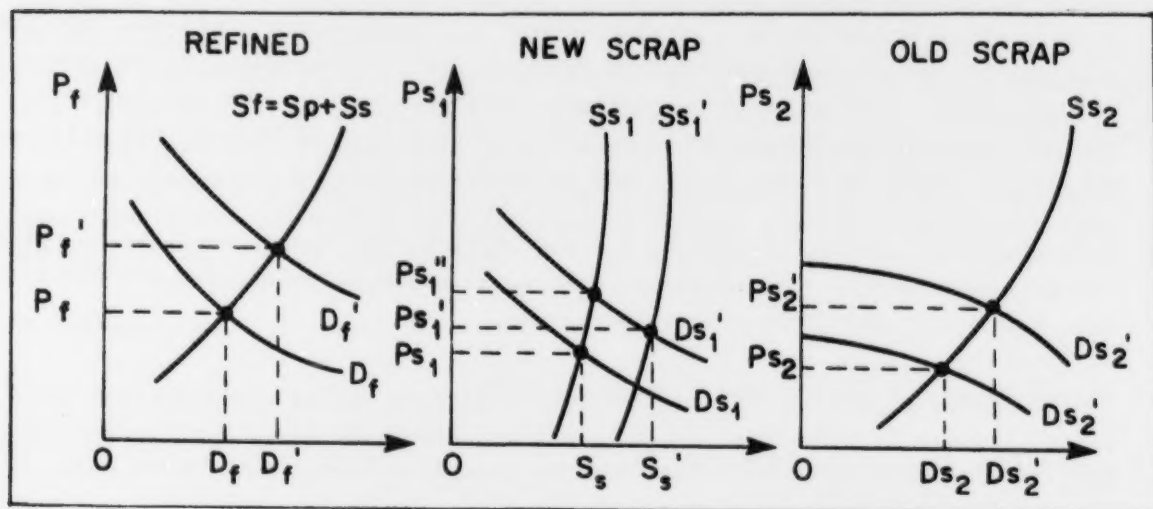


Figure 3. The effects of economic expansion on copper prices

The supply of new scrap has been drawn almost totally unresponsive to increases in price. This is because S_{s1} is simply related to D_f as the result of the technology of its generation. The only possibility of S_{s1} increasing with P_{s1} is through the effect of P_{s1} on copper demand, which, in turn, may affect scrap collection. Thus, if S_{s1} did not shift, P_{s1} would change dramatically (to P_{s1}'') in response to economic conditions. The mitigating factor in keeping P_{s1} down is the shift in S_{s1} with the increase in copper production. If this shift is approximately equal to the increase in demand for new scrap, the scrap price will remain fairly stable and the spread between refined copper prices and new scrap prices will widen during economic booms.

The limit to this price differential is the degree to which brass mills can use copper and scrap interchangeably. If this substitution is high, as one would expect, since essentially only a melting furnace is needed for conversion, then a significant price differential means D_f and D_{s1} shift back and forth until the spread is narrowed, in the extreme case of complete substitutability, to the

(constant) cost of converting scrap to copper. The degree of substitution, which is an empirical question to be discussed in the next chapter, is the only factor limiting what could be extreme volatility of new scrap (number 1) prices, if the shifts in demand and supply were to get out of balance.

Once the new scrap and refined copper markets have adjusted to determine prices and quantities, the secondary refiners' demand for old scrap determines its price. In the third diagram of figure 3, the increase in P_f makes increased production profitable and increases the value of each ton of scrap, shifting D_{s2} upwards. Because P_{s2} rises along S_{s2} and because secondary processors are in competition with primary refiners and cannot increase their refined prices, there generally will be a reduced price spread between P_f and P_{s2} as the market expands, reflecting a lower margin for secondary smelters and refiners.

What ultimately determines the degree to which the primary market expands as the economy expands?⁴⁷ The old scrap market affects the primary market in that the more responsive the dealer supply is to scrap price increases, the more secondary supply will expand to compete with primary metal (and the flatter will be the curve for $S_p + S_s$). The new scrap market is related indirectly to the primary market through the substitution of new scrap and copper by fabricators. New scrap supply increases automatically when copper output expands, and the tendency for the scrap price to fall (given demand) induces customers to substitute scrap for refined copper and to reduce primary copper demand. As previously discussed, this substitution will take place mainly on the part of ingot makers and others that do not need copper of primary quality.

Energy Price Changes and the Scrap Market

The model can also be used to illustrate the effects of energy price changes on the copper market. An increase in energy costs (P_e) affects mine, smelter, and refinery costs for both primary and secondary refiners. The initial effect, therefore, will be to shift the primary and total refined copper supply curves upward, since a higher market price must now be obtained to cover production cost. One would expect S_p to be shifted disproportionately, as primary copper production is more energy intensive than secondary.⁴⁸ Other things being equal, the result would be a higher copper price and a restricted market. However, energy price changes have macroeconomic effects as well, tending to create recessions in countries such as the USA that are large net energy importers and have little energy-related investment (Canada is an importer of petroleum but a net exporter of energy in total).

A petroleum-price-induced recession in the USA would depress durable goods production (DUR) and shift both D_f and D_{s1} to the left. The combination of the demand and supply effects in the model would tend to cause little change in copper or new scrap prices, to lower old or obsolete scrap prices, and to contract sales in all three markets. Because of the relative energy cost advantage of the secondary processors, they would be expected to increase their market share.⁴⁹

This is illustrated in figure 4, by all demand curves as well as refined and new scrap supply curves shifting to the left.

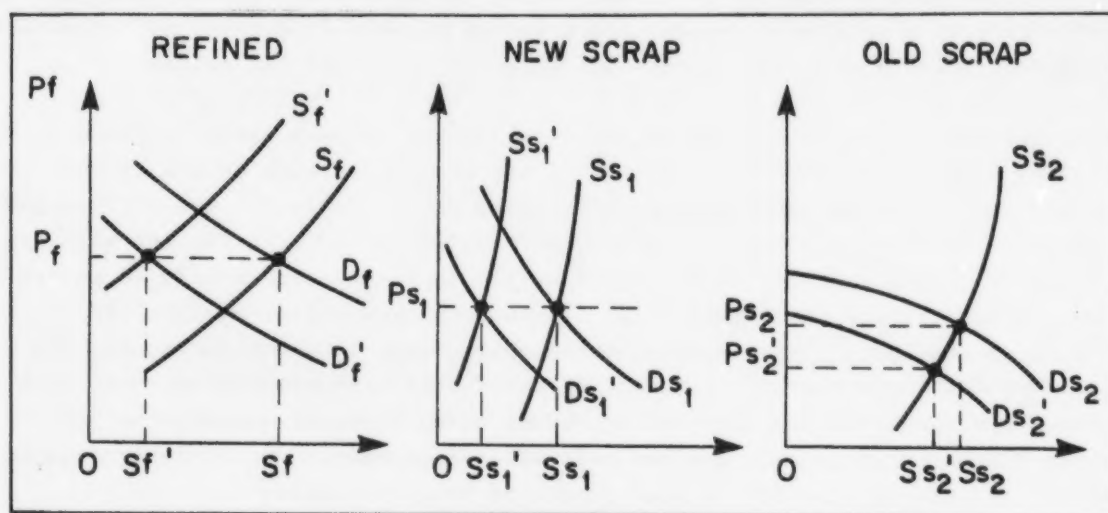


Figure 4. Effects of energy price changes on primary and secondary markets

The disproportionate increase in the free market (LME) price also affects the scrap markets. From figure 3, successful rationing by primary producers results in less copper consumption, and hence less new scrap supply. Higher LME prices also force brass mills that are not given preferential treatment by the primary copper refiners to try to substitute scrap, raising new scrap demand. High-grade scrap prices will, therefore, rise with the free market copper price. Similarly, to the extent that secondary smelters are free both to sell at LME prices and to satisfy copper excess demand (as assumed here), they will expand production, demand more old scrap, and cause its price to rise as well.

An Administered Pricing Model of the Ferrous Scrap Market

The copper market, at least in recent years, is characterized by free and volatile price movements. In contrast, relatively fixed domestic steel prices

have always been a feature of the steel market. As described above, most national steel industries are more or less tightly knit oligopolies (often government controlled) with the influence of supply and demand on prices in the short run making itself felt only in the international steel market. For example, U.S. finished steel prices have tended to rise with industry-wide cost increases, even in the face of a rapidly growing share of imports into the market.⁵⁰ In addition, steel demand has been found not to be responsive to price in the short run.⁵¹ Thus, the indirect effects of scrap prices on finished steel demand tend not to be strong, at least in the short run, and in modelling the ferrous scrap market we shall treat both finished steel output and price as given. The effects of scrap prices on scrap demand will thus be felt only through the substitution of scrap for other materials in a given volume of steel. Steel prices we will take as 'administered' and steel output as depending on conditions in the overall economy only.

The relationship of scrap to primary metal in the steel industry also differs from that of copper as the result of the difference in the structures of the markets. As previously noted, scrap does not substitute directly for steel in the steel market, but competes with pig iron (and indirectly with iron ore) as an input in the steelmaking process. Iron foundries, while similar to ingot makers and brass mills, do not have an analagous role in the market as they are not essentially fabricators that use steel and scrap as inputs, but producers of a parallel product using pig iron and scrap. The steel market is thus conceptually simpler, with integrated steelmakers, electric steelmakers and foundries all using either pig iron or scrap to make steel or a related product.

A further structural feature of the steel industry that has special relevance for scrap demand is the vertically integrated nature of the steel and iron ore relationship.⁵² Virtually all major steel producers have captive iron mines to assure a continuous supply, and this applies to coal as well. Relatively little ore is 'merchant ore' actually traded at arm's length in a market; consequently the quoted prices likely do not represent real production costs. This carries over to the blast-furnace production stage as well, so there is no doubt that the internal cost of hot pig iron as an input to the actual steelmaking process is lower than the price of the excess 'cold, merchant pig iron' sold to foundries. The substitution of scrap and pig iron in steelmaking is greatly affected by the non-market nature of pig iron costs. To the extent that Canadian ore exports are intrafirm sales to the major U.S. steelmakers, the nature of this relationship provides a major advantage over scrap. Of course, the specialty steelmakers and foundries purchase all their materials.

Given the foregoing institutional constraints, a model that will capture most scrap/pig-iron relationships can be derived from the assumption that the major participants in the steel market (the integrated producers, specialty

steelmakers, and ferrous foundries) sell all that is demanded at exogenously fixed prices, but combine the various inputs in such a manner as to minimize total production cost. Total cost will include capital, labour, scrap, and energy costs plus the cost of producing pig iron (including all blast furnace costs and costs of iron ore from captive mines if the steelmaker is vertically integrated). Symbolically, these are:

$$C = iK + wL + Ps_1Ds_1 + Ps_2Ds_2 + PeE_i + PeE_f + Co(D_o, Pe) \quad (8)$$

with Ds_1 and Ds_2 the purchases of new and old scrap, $E_i + E_f$ the energy used in the blast furnace and steel plant, and $Co(D_o, Pe)$ the cost of mining D_o , ore. (For an independent foundry, mine and blast furnace costs are simply added into $PiDi$, the cost of purchased cold pig iron). The total process of transforming ore to pig iron and then steel can be described by a blast furnace production function in which pig iron, Si , is a function $Si(K_i, L_i, E_i, D_o)$: that is, a function of capital, labour, energy, and ore inputs.⁵³ Finished steel, S_f , depends on K_f , L_f , E_f , Si , and Ds_1 and Ds_2 . Our model assumes minimization of total cost, C , subject to the two production function constraints, and an exogenous demand for finished steel ($D_f = S_f$), which depends on durable good production, DUR .

The result of producers' minimizing costs is the same as if they maximize profits and results in conditions similar to equation (4) except that, instead of the value of an input's marginal product, $(P_f dS_f/dD_o)$ etc., equalling its price, in the case of ore production it equals the marginal cost of mine extraction.⁵⁴ Depending on the shape of the mining cost curve, this can make a difference to the ultimate ore-scrap competitive balance. Because of the capital-intensive nature of open-pit mining, one would expect the mining marginal cost curve to be downward sloping over a fairly large range, then flat until close to capacity. If the marginal product of ore declines less steeply than marginal cost at low output, then the integrated firm will have a preference for its own ore over either purchased ore or scrap and will attempt to use its own mines to capacity. The effect on the ore market is illustrated in the third panel of figure 5, with the first two panels representing new and old scrap demand and supply.

If total steel demand is relatively low, ore will tend to be used, even with low scrap prices. Only an increase in steel demand that brings mines close to capacity will cause substitution away from ore as ore costs rise.

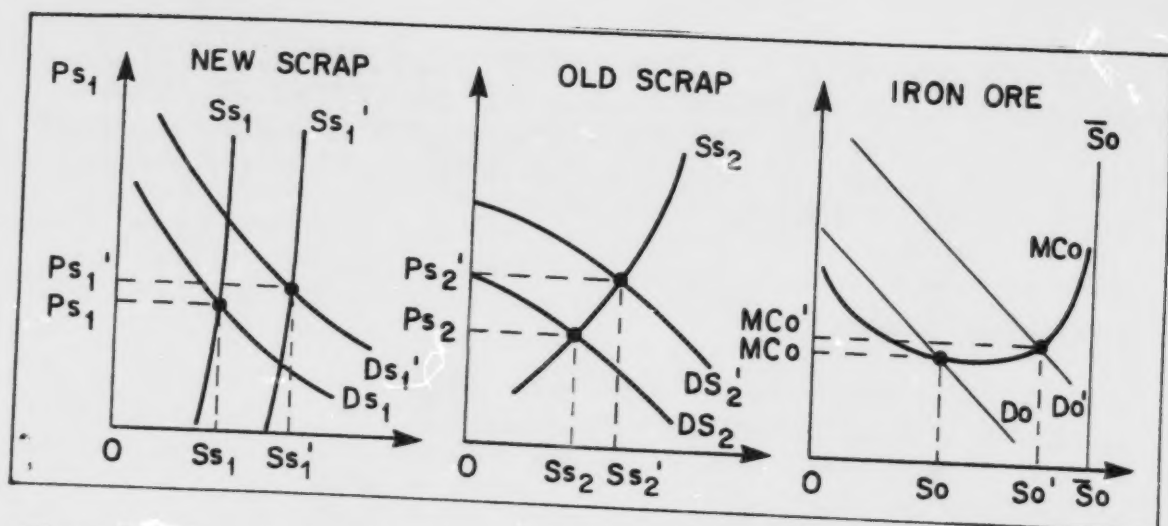


Figure 5. The relationship of scrap and iron ore in steelmaking

The type of furnace in use, however, may impose technical limitations on the use of old scrap, and limit the substitution away from ore even at capacity. While the open hearth and electric furnaces in steelmaking or the cupola foundry furnace can be run with virtually 100 percent scrap, the exothermic nature of the BOF reaction imposes a technical limitation on scrap use. The combination of BOF use and ore ownership by integrated steelmakers makes the scrap demand insensitive to price changes. It follows that short-term substitution of scrap for iron ore occurs either within the OH or cupola furnace or between the BOF and electric furnace, the latter occurring only at less than full capacity. Longer-term substitution, of course, entails the expansion of either BOF or electric capacity, depending on the relative prices of scrap.

Energy Prices and Scrap-Ore Substitution

Although, as in the copper industry, ferrous scrap collection consumes much less energy than the elaborate process of production of pig iron from ore, it is less certain that energy price increases will induce the substitution of scrap for ore. Increases in natural gas, electricity, or heavy fuel oil prices certainly increase ore mining, concentrating, and agglomeration costs. While the coke rate (coke use per ton of pig iron) in blast furnaces declined markedly (.873 to .608) from 1954 to 1972 as the result of the introduction of agglomerates and the use of higher-grade imported ores, this process has been fully completed and cannot now offset ore cost increases. Thus the ore/pig-iron process remains very highly energy intensive in coal, natural gas, fuel oil, and electricity. However, substitution of scrap where possible entails heating the cold scrap,

either in electric furnaces where 100 percent scrap can be used, or by adding the scrap to the hot pig iron in a conventional furnace. There is, therefore, little saving in the steel furnace itself, although it is probable that steel-making from scrap is less energy intensive than the entire mining-to-blast-furnace-to-steel-furnace process.

Scrap Market Dynamics

The dynamics of scrap and metal market price movements result from two sources: speculation by scrap dealers, and the dependence of old scrap supply on the stock of obsolete products, such as junked automobiles, that have built up and are available for recycling.

Speculation on the part of dealers and fabricators derives from the stockholding motive. The decision by a firm to keep scrap or sell it to a dealer is an economic rather than a technological one, and thus will be subject to economic factors. If, for example, new scrap cannot be immediately reused as primary copper, then the copper fabricator, refinery or foundry, can either sell the material in the current period or store it in anticipation of a rise in copper prices. The dealer, upon receiving the scrap and processing it (if it is in fact sold, it becomes new purchased scrap), faces the same decision concerning resale on the market. Both the fabricator and the scrap dealer in effect have the chance to be speculators. They both, if they are profit maximizers, will be balancing the expected increase in the discounted value of the scrap, if it is not sold (and prices are expected to rise), against the cost of scrap storage. If $R_s(t)$ represents scrap in storage and $Q_s(t)$ the scrap sales, the present value of future sales is:

$$PV_o = \int_0^{\infty} \exp(-rt) P_s(t) Q_s(t) dt$$

where $P_s(t)$ represents expected scrap prices at time t in the future. If $C(R_s)$ represents the cost of storage, a rational speculator would maximize PV_o less the present value of costs, or

$$J = PV_o - PC(R_s) = \int_0^{\infty} \exp(-rt) \{P_s(t) Q_s(t) - C(R_s(t))\}$$

subject to $dR_s(t)/dt = -Q_s(t)$

The result of this maximization problem would be that it would pay to hold the scrap in any period when the expected rate of increase in prices exceeded the sum of the interest rate (r) and the real marginal cost of storage (the cost of storing an extra ton divided by the scrap price). Algebraically this is

$$\Delta P_s(t)/P_s(t) > r + MC(Q_s)/P_s(t)$$

If, for any reason, scrap prices are expected to rise by less than this amount, then it will pay to unload the scrap onto a dealer (if one is a fabricator) or back onto the secondary market (if one is a dealer). This condition also provides the reason why one would expect as much excess new scrap as possible to be sold to dealers rather than stored by fabricators; the reason being that the cost of an additional ton of storage capacity in a busy fabricating operation would be much higher than in a dealer's scrapyard. Copper consumers are often in such a hurry to unload their excess scrap that contracts are made obliging dealers to buy all the new scrap generated that cannot be immediately reused, at a predetermined price independent of the current price of scrap. They do this by simply installing containers in the manufacturing establishment that are regularly collected. This practice is accepted by dealers because of the value of obtaining a secure, regular supply. In fact, the contract sometimes goes the other way in dealings between copper fabricators and large primary copper refiners (who also refine scrap, as we have seen). These refiners sometimes engage in the practice of 'tying' the scrap by imposing as a condition of a refined copper sale the automatic and exclusive resale of the generated prompt scrap to the refiner.⁵⁵

Because the generation of new scrap (the clippings, borings, turnings, etc., arising from any manufacturing or fabricating process) tends to be technologically determined by the process, it is virtually independent of the current price of scrap or copper on the market. In fact, since there are more incentives to be efficient in periods of high prices than low, there is an argument that new scrap generation is possibly even slightly negatively related to price because less waste will be produced. From the analysis above, coupled with the observation that the fabricators and foundries are chronically short of storage space for scrap, any new scrap not utilizable as home or revert will be quickly sold to dealers, and thus the supply of new scrap to dealers will be independent of the price of scrap. However, the dealers have considerable storage space and do not have to sell this material immediately whatever the price. Dealers are clearly speculators - it is a major part of their business - and if prices are expected to rise they will tend to hold scrap off the market, and unload only if the current price is high enough to justify the sale. This speculative behaviour on the part of dealers can generate instability in the market if scrap-holding costs are low, as they may in fact accelerate price increases by holding scrap off the market.

Cyclical scrap price movements can also be generated by the adjustment of obsolete product stocks. This was symbolically represented by the inclusion of the variable $A(t-1)$ to represent the pool of available scrap in the supply function for obsolete scrap: i.e. $Ss2 = Ss2(Ps2, A(t-1))$. This pool of available

scrap is not constant, however, but changes slowly as scrap is generated by the obsolescence of metal products and is depleted by dealers' collection. This is described by the equation of change:

$$\Delta A(t) = A(t) - A(t-1) = G_t - S_s(P_{s2}(t), A(t-1))$$

with $G_t(D_f)$ representing scrap generation as a function of the demand for new products.⁵⁶ The obsolete scrap market is thus a dynamic system and the short-run supply curve, before $A(t)$ has had a chance to adjust, will be different from the long-run supply curve, which applies after $A(t)$ has adjusted fully.

How the dynamic nature of the scrap market affects price stability depends on the relative elasticities of demand and supply. In figure 6 an increase in durable goods output will increase the demand for scrap and result in an initial price increase to P_{s2} along the short-term supply curve for a given scrap inventory level. If the increased products in use subsequently increase the available scrap supply, the short-term scrap supply curve will later shift right and result in a fall in P_{s2} relative to the initial high price. In this case the long-term supply curve (which obtains when $A(t)$ settles at its new equilibrium

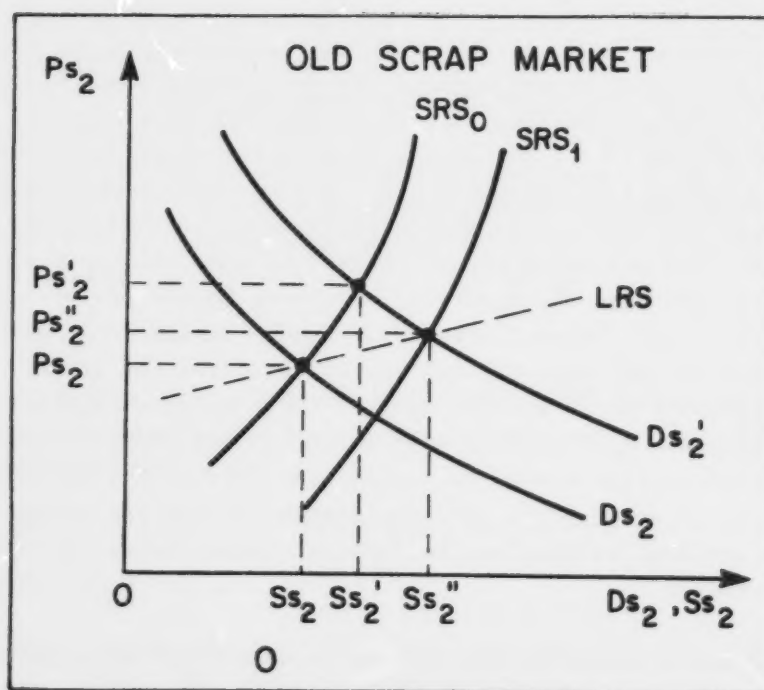


Figure 6. Short-term and long-term scrap market adjustment

level and $\Delta A(t) = 0$), is flatter than the short-term curve, as a result of the supply adjusting slowly over time. An increase in scrap demand that did not result in an equal increase in scrap generation (for example, as the result of changes in the relative costs of primary and secondary metal) could result in an increasing price spiral adjustment. In this case the initial shift in Ds_2 would increase price along the short-term supply curve but the increased supply now exceeds scrap generation, leading to a depletion in scrap availability ($\Delta A(t) < 0$).

The decrease in scrap stocks would now shift the supply curve to the left, increasing price even further and encouraging further depletion in a price spiral which would continue until scrap stocks and collection fell to the point where generation again equalled collection. This means that, if prices were uniformly high in the recent past for a period long enough to deplete the stock, then an increase in demand would lead to even higher prices; on the other hand, if prices were low in the past, they would continue to be low.

5. EMPIRICAL RELATIONSHIPS OF SCRAP AND PRIMARY COPPER

Introduction

This chapter applies the framework of analysis developed in chapter 4 to the relationships between primary and secondary copper in the U.S. market. We employ estimates from previous studies as well as our own econometric work on the elasticities of demand and supply for primary copper and for scrap to formulate a policy model of the North American copper industry embodying the relationship of scrap and primary copper. With this model we then discuss three issues of concern to industry and policy planners:

- i declining ore grade;
- ii increasing energy prices;
- iii U.S. environmental pollution regulations on scrap and primary prices.

All of the above can affect the primary-secondary copper balance.

The following section outlines the general form of the policy model. We subsequently form elasticity estimates of the demand and supply relationships and perform policy simulations in the final section.

The Structure of the Empirical Model

The copper market model developed in the last chapter was in principle comprehensive enough to determine prices and quantities sold in three copper markets for refined, new, and old scrap. With estimates of the coefficients in such a model, one could predict the effects of changes in exogenous variables, such as energy prices, on all the variables in the model. In this chapter the model is rewritten in a slightly more realistic form to include the possibility of U.S. trade in copper and scrap and to take account of the divergence between U.S. producer prices and the free market prices that occurred from 1960 to 1978. It describes the demand and supply equilibrium in the refined, new and old scrap markets by means of the following five equations:

$$Df(P_p, P_f, P_{s1}, Dur) = Sp(P_p, w, g, P_e, K_p) + Ss(P_{s2}, w, P_f, K_{ss}) + Mf \quad (12)$$

$$Ds_1(P_p, P_f, P_{s1}, Dur) = Ss_1(Df) \quad (13)$$

$$Ds_2(P_f, P_{s2}, P_e, K_{ss}) + Ss_2(P_{s2}, P_e, A(t), P_{ss}) - Ssx \quad (14)$$

$$P_p(t) = f(Mf(t-1)) \quad (15)$$

$$A(t) = A(t-1) + Df(t) - Ss_2(t-1)$$

(16)

The model has been changed by adding the variables Mf and Ssx representing refined copper imports and scrap exports respectively, and by allowing the primary producer price (Pp) to differ from the free market refined copper price (Pf). The latter is necessary because during the 1960s and 1970s (until 1978) a system of administered pricing existed in the U.S. copper market in which producer prices were adjusted only slowly in response to market forces. Although the producer prices now respond much more quickly to free market prices, the slow adjustment took place over most of the period for which the model will be estimated and thus must be allowed for. It has been assumed that copper imports (depending on the excess of U.S. producer over LME prices as well as a U.S. durable goods index) were the main factor affecting producer prices. The three market-determined prices Pf , Ps_1 and Ps_2 , representing the COMEX or LME, new scrap, and old scrap prices respectively, are determined by the equality of market demand and supply in equations (12) to (14). Both Pf and Pp are included in the refined copper and new scrap demand functions, assuming some consumers are allowed to buy at Pp (during two-price system operation) while others must pay the free market (LME or COMEX) price. The final equation shows the change in obsolete scrap stocks.

The exogenous variables in this model are Dur , g , Pe , Pss , Kp , and Kss , representing respectively: a durable goods index; the grade of ore mined by primary producers; an energy price index; the price of scrap steel; and the levels of mine and secondary smelter capacity. Both falling grade and higher energy prices increase primary producer costs and reduce mine and refinery production for a given producer price. This will raise Pf , the scrap prices, and put upward pressure on the producer price, with the additional consequence of causing substitution away from primary to secondary copper. The grade of ore mined has been assumed exogenous because it tends to change slowly over time with ore depletion, unlike the cutoff grade or the average grade within the ore, both of which one would expect would be affected by metal prices. An increase in the scrap steel price affects the copper market because a certain amount of copper scrap is collected from radiators and castings in automobiles, which are also the major source of ferrous scrap. An increase in Pss should lower the number 2 scrap copper price, Ps_2 , increase the output of secondary refiners, and finally lower refined copper prices. Environmental pollution regulations increase the operating costs of both primary and secondary smelters and refiners, as well as constraining the additions to capacity for both, making Kp and Kss lower than they otherwise would be. This raises primary prices, of course, but as it increases the costs of scrap processing it may either increase or decrease the price of scrap and the relative outputs of scrap and primary production. In the following sections we look at the magnitudes of these effects.

The Elasticities of Primary and Secondary Copper Demand

The Demand for Refined Copper and New Scrap

Several models of the copper industry have been published in the recent years, and most have statistically estimated a function for U.S. copper demand. Typically, total refined copper consumption (including scrap) is related to the U.S. index of durable goods production (Dur) and the Engineering and Mining Journal copper price (Pemj), a weighted average of the U.S. producer and LME prices. Since much of the post-war substitution for copper has been in favour of aluminum, the aluminum price deflated by the wholesale price index is usually included, the deflation attempting to take care of the substitution of other materials. A distinction is also made between short- and long-term demands, a year being effectively the short term for the copper industry because of the long lags in changing both demand and supply.⁵⁷ Price elasticities are defined both for the short and long term (after all adjustment has been made), and are shown in table 10, which summarizes several estimates of the overall elasticity of demand for refined copper, including a regression by the author (shown in appendix II). (Elasticity refers to the percentage change in demand with respect to a 1 percent change in the selected variable.)

With the exception of the long-run elasticity estimates by the Charles River Associates (CRA), a finding that is somewhat suspect econometrically, there is remarkable agreement in the figures shown in table 10 that copper demand is inelastic (not responsive) with respect to price changes, a finding consistent with the magnitude of year-to-year price changes in the free copper markets (LME and COMEX). Excluding the long-term CRA findings, the average of the estimates for the short and long term are respectively, $-.29$ and $-.68$ for own price, $.49$ and 1.14 for the aluminum price, and $.69$ and 1.41 for an index of industrial activity (alternatively, the Federal Reserve Index of Durable Manufacturers or the Index of Industrial Production). Without discussing the estimation methods further, we shall take these values as plausible estimates for the responsiveness of total copper demand to price.

While overall copper demand (both refined copper and new scrap) is relatively unresponsive to price changes in the short term, there is evidence to suggest that within this total the substitution of new scrap for refined copper is very price-responsive. There are several reasons for this. New scrap of high grade (brass mill grade or number 1 copper scrap, for example) can simply be added to refined copper in a melting furnace to produce the required alloy. Ingot makers in the USA seem to consist of a very large number of small firms in fierce competition to produce a similar product. Since any one firm cannot pass on its cost in the final price without losing sales, the firm will be very responsive

to the price of scrap, especially since new scrap is nearly 60 percent of the total material input to this industry. Brass mills, included with ingot makers in the available statistics, appear to be more vertically integrated and less competitive but have similar opportunities for substitution.

Prompt scrap is also close to primary copper in quality, being largely uncontaminated by insulation or other metals. Since it is also of known composition, a crucial factor in the metal recycling business, it should be readily substitutable for primary copper.

Table 10. ESTIMATED ELASTICITIES OF REFINED COPPER DEMAND

	Own Price		Aluminum Price		Activity Variable	
	Short Term	Long Term	Short Term	Long Term	Short Term	Long Term
Charles River Assocs.	-.21	-2.88	.41	6.50	.26	3.56
Fisher et al.	-.21	-.90	.24	1.01	.33	1.40
Hartman	-.47	-.64	.61	.84	1.30	1.78
MacKinnon and Olewiler		-.33			n.a.	n.a.
McNicol	-.33	-.77	.66	1.57	.44	1.06
Slade	-.21					
Stollery	-.14					
					1.08	

Sources: Charles River Associates, Economic Analysis of the Copper Industry, 1970; Fisher et al., 'An Economic Model of the World Copper Industry,' Bell Journal, Autumn 1972; R. Hartman, 'An Oligopolistic Model of the U.S. Copper Industry', MIT Ph.D. Thesis, 1977; D.L. McNicol, 'The Two Price Systems in the Copper Industry', MIT Ph.D. Thesis, 1973; M. Slade, 'The Effects of Higher Energy Prices and Declining Ore Quality', Resources Policy, 6, no. 2, Sept. 1980; J. MacKinnon and N. Olewiler, 'Disequilibrium Estimation of the Demand for Copper,' Bell Journal, Spring, 1980.

Although no previous estimates of this cross elasticity have been made, an idea of the substitutability of new scrap and refined copper can be obtained by plotting the ratio of their use by brass mills and ingot makers over time. This is shown in figure 7, and indicates a range of from 25 percent to nearly 50 percent scrap to total metallics, with considerable yearly variation. This visual impression is confirmed by an equation relating the scrap-to-copper ratio in ingot makers and brass mills to the relative prices of scrap and LME copper. This equation gives an estimated elasticity of about -4.0 within two years, probably an underestimate since the correct scrap price could not be employed.⁵⁸

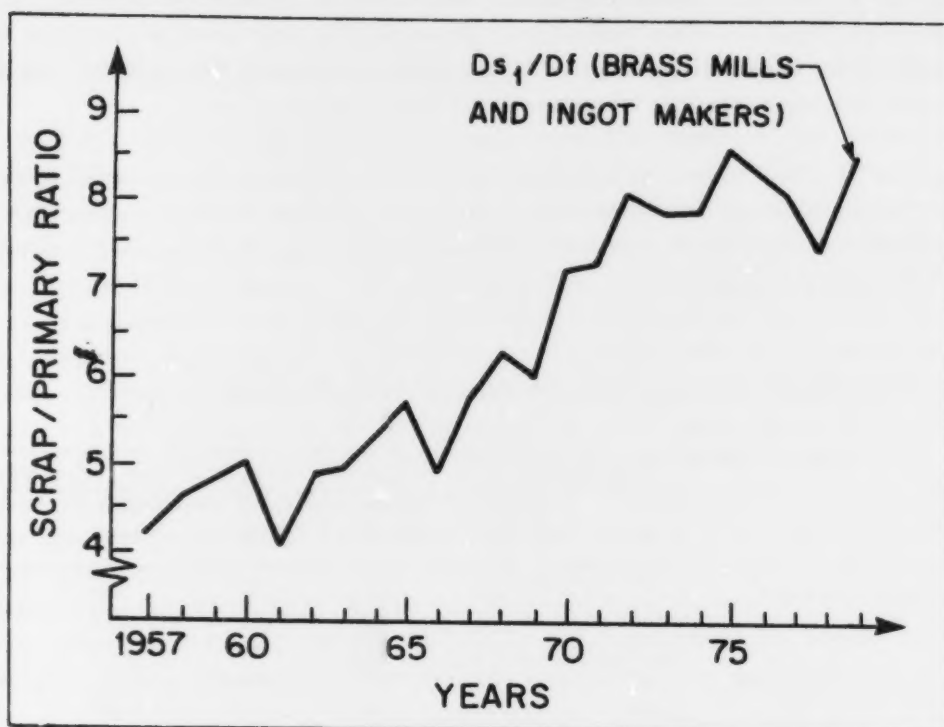


Figure 7. Ratio of new scrap to primary copper consumption by ingot makers and brass mills

The high estimated elasticity (and the problem of obtaining a separate new scrap price) justifies the simplifying assumption made by other copper market analysts: namely, that the elasticity of refined copper to new scrap substitution is infinite. In other words, the two are effectively perfectly interchangeable substitutes. This assumption implies that P_{s1} and P_f should move together in lock-step fashion, separated only by the conversion cost of new scrap to refined copper,⁵⁹ and that new scrap and primary supply and demand could be summed as effectively the same material. We shall see that this assumption considerably simplifies the model, with relatively little cost in loss of accuracy.

The Demand for Obsolete Copper Scrap by Secondary Refiners

According to the theory in chapter 4, scrap demand by secondary refiners (given the assumptions that they are in a competitive market and maximize short-term profits) can be derived as a function of P_{s2} , P_f , and the costs of labour, energy, and other materials used in processing. Under these assumptions, it

will be recalled, profit maximization by both processors and dealers leads to an efficiency condition in the market in which the price of a pound of obsolete scrap is just equal to its marginal 'worth' to processors, represented by the equation:

$$P_f \frac{dS_s}{dD_{s_2}} = P_{s_2} \quad (17)$$

where dS_s/dD_{s_2} is the extra amount of refined metal obtainable from an extra pound of obsolete scrap (generally grade 2 or below).⁶⁰ If this 'marginal product' declines as more scrap is used, the inverse of this function represents the demand for scrap (D_{s_2}), shown in equation (14).

As the secondary refiners' gross margin of refined over scrap prices widens, the refiners should demand more scrap, an activity that will subsequently narrow the margin again as scrap prices are driven upward. Figure 8 illustrates the historical relationship between the scrap-primary margin, defined as $(P_f - P_{s_2})/P_f$, and secondary refiners' scrap purchases. Purchases do indeed appear to react to the profitability of scrap conversion, with a lag of approximately one year. More formally, the statistical relationship between the variables (shown in appendix II) appears to indicate that the relationship is fairly strong, with scrap demand elastic, or increasing more than proportionally to an increase in

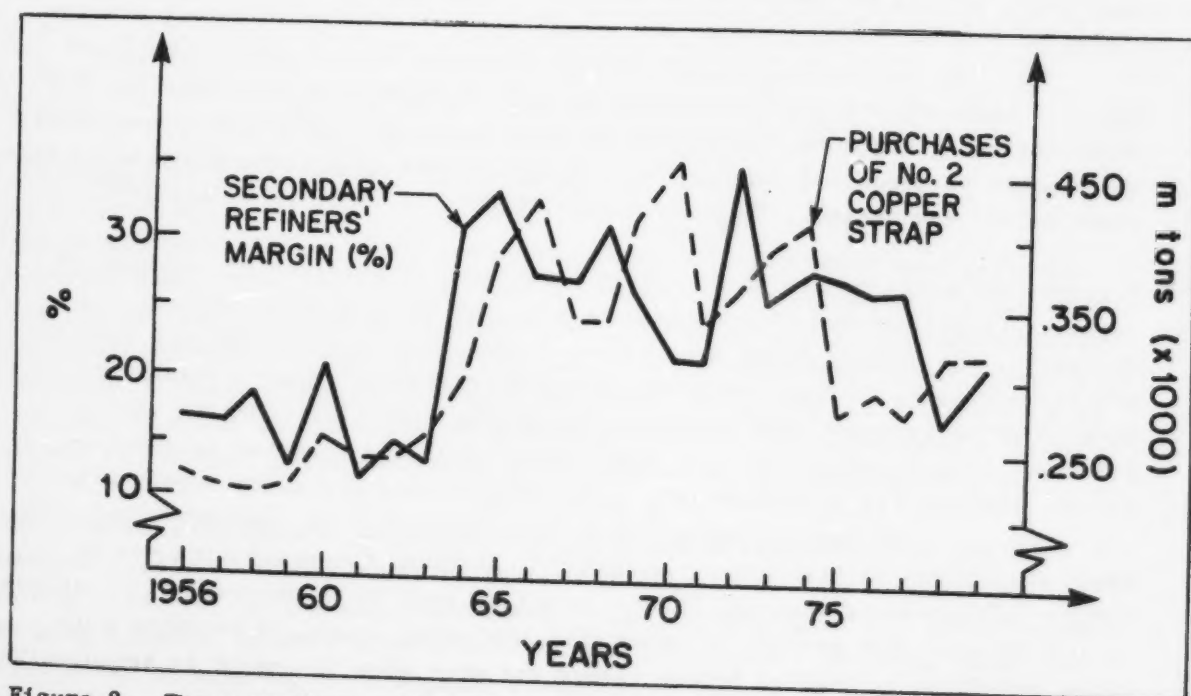


Figure 8. The secondary refiners' scrap-primary margin and their purchases of scrap

Pf or a decline in Ps_2 . The estimate of the elasticity of scrap demand is in the neighborhood of -1.3. Scrap demand also responds negatively to increases in electricity prices, with an elasticity of about -.60

The Supply of Scrap and Secondary Copper

The Supply of New or Prompt Scrap

Because the generation of new scrap is proportional to the amount of copper used in fabricating, in the absence of the speculative behaviour discussed in the last chapter we expect new scrap supply to be unresponsive to price. The ability of a dealer to speculate by holding scrap off the market in low price periods depends on the size of the dealer's operation and his ability to finance large scrap inventories.

The extent of speculation by scrap dealers is uncertain. What is clear is that only the large dealer-brokers described in chapter 2 will have the capital for extensive speculation. Although the scrap industry is composed predominantly of small companies, the large dealers who act in a brokerage capacity are in a strategic position for such activity. The discussion in chapter 3 indicated that there will be an incentive to hold scrap off the market when prices are rising as long as interest rates and other costs of holding inventory are low.

Figure 9 shows the ratio of new scrap to copper consumption from 1960 to 1979. While following a general upward trend, there is considerable yearly variation, which might be accounted for by price responsiveness if dealers temporarily held supplies off the market. This is especially true in 1973, 1974, and 1979.

Previous estimates of new scrap supply have found no evidence of speculative activity by dealers and no responsiveness of new scrap sales to price. Bonczar⁶¹, the Charles River Associates, Fisher et al., and Slade all estimate new scrap supply, finding new scrap linearly related to copper consumption only, with no price response, and coefficients ranging from .225 (CRA) to .396 (Fisher). A regression for data from 1957 to 1979 and reported as equation (2) in the appendix II, does, however, find a significant new scrap supply elasticity (.355 over one year; t-value 5.6). This regression is also preferred over earlier versions on statistical grounds.⁶² Although the statistics may be unduly influenced by what may in the future be seen to be abnormal fluctuations in the 1974 to 1979 period, it seems that new scrap supply is becoming more price sensitive as dealers become larger and more able to engage in speculative activity.

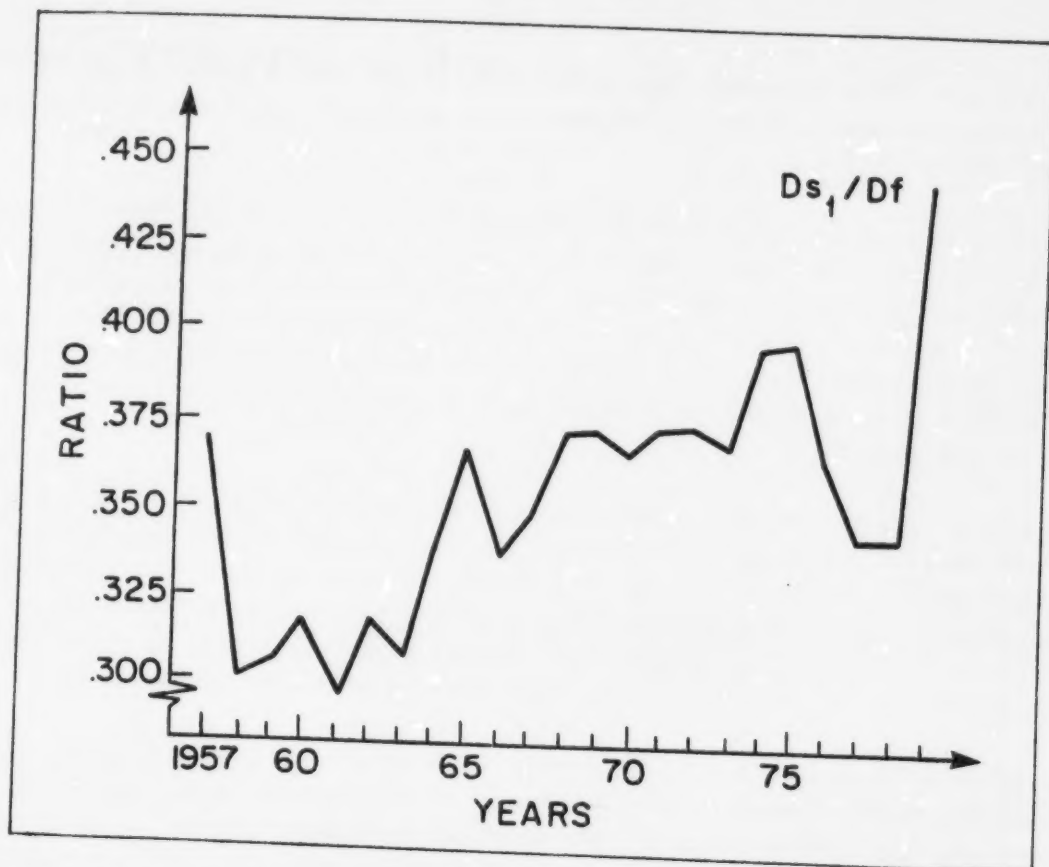


Figure 9. Ratio of U.S. prompt scrap to copper consumption, 1957-79

The Supply of Obsolete (Old) Copper Scrap

The supply of secondary copper recovered from old scrap has a very different economic basis from that of new (prompt industrial) scrap, depending not on current industrial consumption of copper, but on the reservoir of copper existing in junked products throughout the country, and on the transport and other costs required in the reclamation of these products. Because of this dependence of the flow of scrap on the stock of obsolete products, old scrap supply is a source of cyclical price behaviour, as discussed in the previous chapter.

The reservoir of copper in obsolete junked products represents the absolute maximum supply of copper scrap to dealers in any period. It is depleted by dealer scrap collection and replenished by the discarding of old products containing copper. Usually only a fraction of the reservoir of scrap copper is recovered, because there is a great variation in degree of contamination of the copper and cost of its recovery within the reservoir. In addition, if the discarded products are not reclaimed quickly, they are usually relegated to a sanitary landfill and never recovered. While accurate estimates of the size of

the obsolete copper reservoir are impossible, it has been hazarded that, of total obsolete copper material, 70 percent is unrecoverable at current and foreseeable scrap prices.

While the pool of copper-in-junk is depleted by the recovery of copper scrap, it is replenished by the discarding of old products containing copper. The rate of addition to the copper-in-junk depends in turn on the amount of copper contained in durable goods currently in use by the public and the lifetime of these products. The copper-in-use is thus a secondary reservoir of scrap copper which is replenished in turn by the sale of new durable goods. Figure 10 illustrates the flow of old copper.

The size of the reservoir of copper-in-use and the rate at which scrap copper becomes available through discarding of products depends on the copper contained in thousands of different products and their intrinsic rates of depreciation or obsolescence. While accurate computation of the life cycles of every copper product is impossible, rough estimates derived from U.S. Bureau of Mines figures are given below in table 11 for the broad sectors of copper product use.

The average life cycle for all copper products is 17 years, according to Carillo⁶³, and less than 20 percent overall of obsolete scrap ultimately is recovered. The lowest recovery rate occurs in consumer durables, since even with the lowest life cycle the costs of collection are higher and the copper content is lower than for industrial pure copper products such as copper wire, of which over 40 percent is reclaimed. In terms of these broad sectors, most copper is reclaimed either from electrical products (wire, busbars, etc.) or industrial machinery. Less than 20 percent of total copper reclaimed is

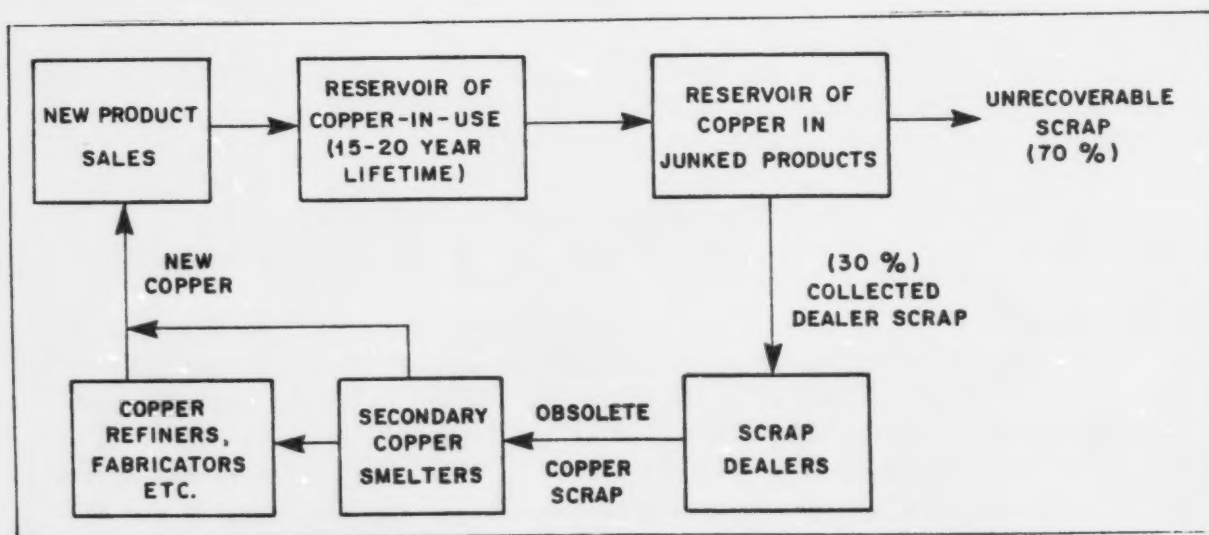


Figure 10. The cycle of obsolete copper scrap

Table 11. COPPER PRODUCT LIFE CYCLES

Sector	Life Cycles (years)	Percent Now Recovered
Brass mill items (sheet, rod, and tube):		
Construction	9	44
Transportation	9	44
Consumer and general	9	20
Industrial machinery	18	40
Other copper products:		
Construction	29	29
Transportation	9	36
Consumer and general	7	20
Industrial machinery	18	35
Electrical	19	42

Source: F. Carillo et al., Recovery of Secondary Copper and Zinc, U.S. Bureau of Mines 1974, p. 8, table 1.

reclaimed from copper used in automobiles (and the transportation share is falling), unlike ferrous scrap, for which automobile scrap provides a large proportion of the total. Of the copper in a 1963 automobile, nearly 85 percent was obtained from five items, the radiator, generator, starter, heater core, and body wiring, that are easily removed prior to shredding or bundling.⁶⁴

While in principle the life cycles for each product category should be utilized in estimating old scrap supply, in practice most researchers have related old scrap generation to the total stock of unreclaimed copper, in effect assuming little change in the product mix over time. The stock changes each year by the difference between the consumption of copper products (net of new scrap) and the amount of copper reclaimed. As table 12 indicates, the stock of unused copper has been growing rapidly in the post-war period, because the growth in copper consumption (2.3 percent on average) has considerably exceeded that for old scrap (.6 percent). The fact of growth in the pool of copper-in-use does not necessarily mean that all this copper is potentially recoverable. That depends on the assumption made concerning the proportion of the obsolete reservoir that is ultimately unrecoverable. Table 12 was compiled on the assumption that there are no truly dissipative uses of copper, and that all is ultimately recoverable at some scrap price sometime in the future.

At the other extreme, some researchers have assumed that, if junked products are not salvaged in the same year, they will never be recovered. Under this assumption there is, by definition, no growth in the reservoir of obsolete products, only in the reservoir of copper-in-use.

Probably an intermediate position is reasonable, but it is very difficult to determine what proportion of junked products in a given year is not recoverable at any given scrap price. Although as much as 80 percent is now unrecovered, one would expect the ultimate proportion to be much lower than this, because there are few truly dissipative uses for copper. For example, before the advent of auto shredding, the 5 percent or so of copper in instruments and small wiring was usually left in the car prior to bundling, because recovery was not economic.

Table 12. GROWTH IN THE RESERVOIR OF COPPER CONTAINED IN END USE OR OBSOLETE PRODUCTS IN THE UNITED STATES, 1957-79.
(1000 short tons)

Year	Copper Use	Old Scrap	Old Scrap Ratio	Change in Reservoir	Level of Reservoir
1957	1935.9	444.5	.208	1532.6	1805.3
1958	1791.5	411.4	.208	1418.1	3223.4
1959	2061.1	471.0	.207	1633.7	4857.1
1960	1920.4	429.4	.203	1530.8	6387.8
1961	1991.8	411.1	.187	1618.8	8006.6
1962	2104.2	415.7	.179	1727.0	9733.6
1963	2343.0	421.8	.163	1960.3	11694.0
1964	2466.8	473.5	.174	2037.1	13731.0
1965	2722.2	513.4	.171	2256.4	15987.0
1966	3111.1	534.8	.156	2625.8	18613.0
1967	2540.7	482.6	.172	2102.7	20716.0
1968	2581.0	520.8	.183	2108.4	22824.0
1969	2933.7	574.9	.178	2412.0	25236.0
1970	2767.2	504.1	.165	2309.8	27546.0
1971	2653.4	445.2	.152	2249.5	29795.0
1972	2883.3	458.2	.144	2467.5	32263.0
1973	3093.7	486.2	.143	2652.5	34916.0
1974	2822.9	483.4	.155	2384.2	37300.0
1975	1982.1	369.2	.169	1647.1	38947.0
1976	2522.3	419.2	.151	2141.9	41089.0
1977	2733.2	451.9	.150	2323.1	43412.0
1978	3048.2	516.0	.154	2579.9	45992.0
1979	3233.5	664.7	.187	2630.3	48622.0

Source: U.S. Bureau of Mines, Minerals Yearbooks.

After shredding and magnetic separation, much of this is now quite cheaply recovered (and incidentally, is less of a contaminant in ferrous scrap). Perhaps the only truly dissipative uses of copper are chemical (in sulphates, etc.), constituting perhaps 10-25 percent of copper use. A study by the Charles River Associates assumed 25 percent dissipation and this seems reasonable.⁶⁵

The size of the reservoir of obsolete products is important because it affects the supply of obsolete scrap in any given period. The collection of old scrap is much less geographically localized than that of new scrap. Truckers, farmers, public utilities, and railroad yards collect old scrap and sell to dealers, who are located in the most highly industrialized metal-intensive areas. In the United States scrap dealers tend to be located in New York, Pennsylvania, Ohio, Illinois, and California.

The collection radius of a scrap dealer for old scrap depends on the density of scrap availability per area, on the cost of transportation, and on the price of scrap. The density of scrap availability depends on the reservoir of obsolete products and products in use, distributed generally according to population. Thus, total old scrap availability is $S = oA$ where o is average density and A is collection area. If transport costs of collection depend on the collection radius they will indirectly depend on collection area, since $A = \pi r^2$ and $r = \sqrt{(A/\pi)}$. If P_s is the scrap price, revenue is $R_s = P_s S = P_s oA$. Costs are $C = C(A)$, and dealer profits will be

$$P_s oA - C(A)$$

A dealer maximizing profits will set P_s equal to the marginal cost of collection area or $MC(A)$. The higher the price of scrap, or the higher the density of available scrap, the larger the area in which it will be profitable to collect or to pay for collection by others. At the cutoff radius there will be zero profit on scrap, with profit increasing the nearer to the dealer location the scrap was obtained. Because copper has a much higher value relative to weight than ferrous materials, one would expect copper scrap dealers to collect over an area much wider than that of a localized scrap iron dealer.

The relationship of scrap density or availability to the size of the obsolete copper reservoir makes the relationship of obsolete scrap supply to the price of scrap contain an unusual time dimension. If P_s increases for a given o density, the scrap collection area will increase immediately leading to a greater supply of scrap. This is the short-term response, or elasticity of supply. However, after a period of time increased collection will deplete the higher-grade and easily-reclaimed part of the scrap reservoir; the density will decline, reducing scrap supply in subsequent periods. Thus, the supply of obsolete scrap in period t depends not only on the price in period t but in period $t-1$, $t-2$, etc. This relationship, illustrated in figure 11, operates independently of speculation in the market which, as we have seen, also will cause a relationship between current supply and past prices.

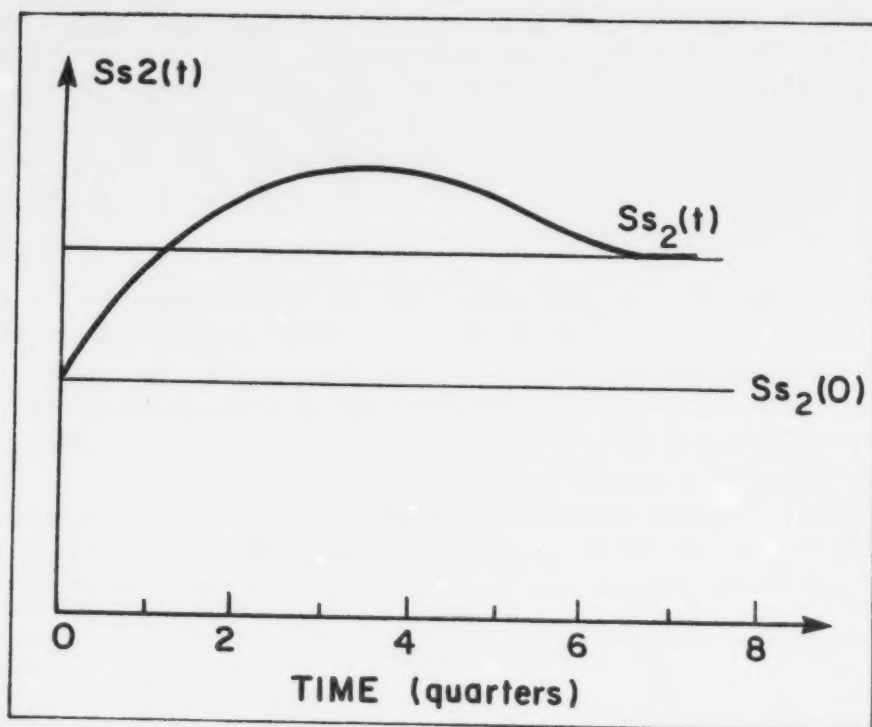


Figure 11. Supply response of old scrap dealers to increase in scrap prices

The figure indicates that the responsiveness of obsolete scrap to an increase in price should be greater in the relative short term than in the long term. The fact that there is a permanent addition to supply, so the curve does not fall to zero or back to the original level, is the result of the long-term effects of price on the life cycles of products. At high scrap prices one would expect product life cycles to contract somewhat, because industrial products especially will be scrapped sooner if their scrap value increases relative to the initial purchase price. This ultimate shortening of product life cycles will cause a permanent shift of copper from the reservoir of copper-in-use to copper-as-scrap and replenish the latter reservoir.

The supply of old scrap can be estimated either by including a distributed lag of past prices directly in the function, or by including both the current price and potential scrap as variables. Both methods have been employed in empirical studies. Bonczar et al., employing the former technique, found the strongest relationship of old scrap with the price lagged one quarter and three quarters; they computed a supply elasticity of .45 after five quarters, and a long-term elasticity of .26. Other studies have attempted to relate old scrap supply to

scrap stocks. The Charles River Associates attempted to take stock changes into account by, in effect, substituting the stock relation found in equation (5) directly into the scrap supply curve. If the function for Ss_2 is assumed linear in price and $A(t)$, it becomes:

$$Ss_2 = a + b_1 Ps_2 + b_2 \sum Df(t-i) - b_3 \sum Ss_2(t-i) \quad (8)$$

assuming all current consumption goes into stocks. Not having an estimate for stocks, the CRA regression included only PS_2 and $Ss_2(t-i)$, calculating a short-term elasticity of .47 and a long-term elasticity of .31. A regression shown in the appendix II cumulates copper consumption and withdrawals from the scrap reservoir from 1957 to estimate equation (8) more exactly. The results were .33 and .05 for the short and long term, respectively. Other researchers have attempted to build a series for scrap stocks and include this variable directly. Fisher et al. began with an arbitrary stock in 1946 and cumulated additions and withdrawals. A similar technique was employed by Slade (1980a) who, however, was more realistic in not assuming a single year lag between consumption and availability, instead employing estimates of average lifetime such as those in table 11. Table 13 compares the various estimates, which in fact are quite similar irrespective of technique.

Table 13. COMPARISON OF OLD SCRAP ELASTICITY ESTIMATES

Source	Short Run	Long Run
Bonczar	.45	.26
Charles River	.47	.0
Fisher et al.	.42	.31
Hartman	.0	.0
Slade (1980a)		.29
Slade (1980b)	.42	.28
Stollery	.33	.05

Sources: Elizabeth Bonczar et al., An Economic Analysis of the Determinants of Metal Recycling in the U.S. (Harrisburg: U.S. Bureau of Mines, 1975); Charles River Associates, Economic Analysis of the Copper Industry (1970); Fischer et al. 'An Economic Model of the World Copper Industry', Bell Journal, (Autumn 1972); R. Hartman, K. Bozdogan and R. Nadkarni 'The Economic Impacts of Environmental Regulations in the U.S. Copper Industry' Bell Journal (Autumn 1979); M. Slade, 'The Effects of Higher Energy Prices and Declining Ore Quality', Resources Policy 6 no. 2, September 1980; M. Slade, 'An Econometric Model of the U.S. Secondary Copper Industry: Recycling vs Disposal', Journal of Environmental Economics and Management, vol. 7, 1980.

The Supply of Secondary Refined Copper

The supply of refined copper by secondary refiners is, of course, derived largely from old scrap. Whether secondary smelter supply varies with the prices of scrap and primary metal and with the costs of processing depends, as we have seen, on the degree of utilization of capacity. For a given scrap price, Hartman et al. (1979) have estimated the secondary refiners' supply curve to be essentially flat in periods where production is well below capacity. In Hartman's estimation, even if the scrap price remained constant, as capacity was approached the other processing costs would begin to increase, causing the supply curve to turn upward at about 70 percent of capacity. In addition, however, if scrap supplies are relatively tight, the price of scrap may begin to rise before this, shifting the processors' supply curve upward in a manner tracing out the old scrap supply curve. The secondary refiners' supply response thus reflects a combination of old scrap supply elasticity and the degree of capacity utilization, as shown in figure 12. The supply curve can, of course, shift in response to exogenous changes in processing costs, such as energy.

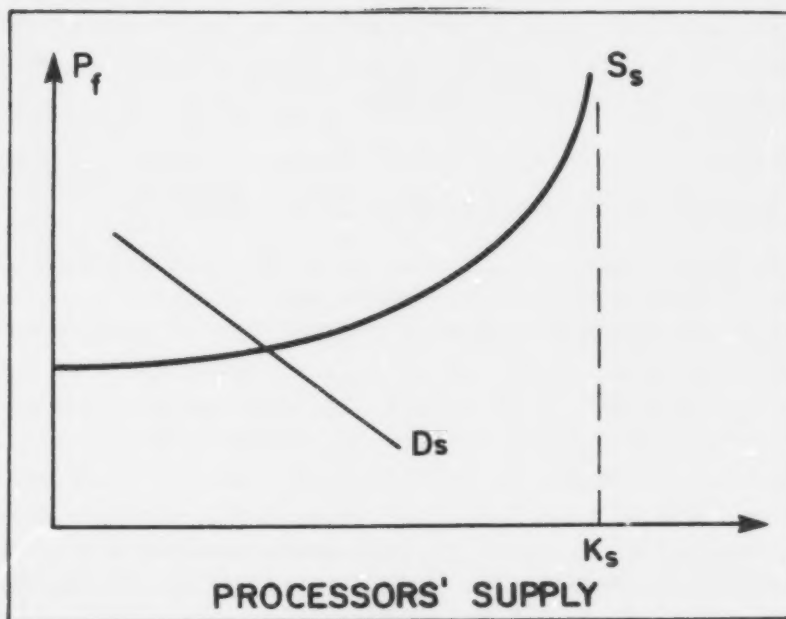


Figure 12. Secondary processors' supply curve

How close the secondary refiners have been to capacity can be calculated from capacity estimates provided by Hartman (1977) and output figures from the U.S. Bureau of Mines Minerals Yearbooks. They are reproduced in table 14, along with the degree of capacity utilization. It is clear that secondary supply was well under capacity for the years prior to 1974.

Table 14. ESTIMATES OF SECONDARY PROCESSOR CAPACITY UTILIZATION

Years	Primary Capacity (1000 tonnes)	Secondary Capacity (1000 tonnes)	Capacity Utilization (percent)
1950	1272	181.8	94.7
1960	1889	285.0	88.8
1970	2156	276.4	83.8
1971	2263	276.4	65.4
1972	2199	276.4	76.9
1973	2176	413.5	57.5
1974	2176	413.5	51.9

Source: R. Hartman, 'An Oligopolistic Model of the U.S. Copper Industry' (MIT, Ph.D. thesis, 1977), p. 40.

The overall elasticity of processor supply can be estimated from a regression performed by Hartman et al. (1979), and by one performed for this study. Hartman's relation of processors' supply to price showed no relationship of price to output up to 70 percent of capacity (with the scrap price constant), the supply curve shifting only in response to scrap price changes. No elasticity was provided, but a 1-cent change in Ps_2 was associated with a .71-cent change in P_m as the supply curve shifted. A regression of secondary supply directly related to the LME price (P_f) (shown in appendix II) in contrast estimated a secondary supply elasticity of .74 (quite responsive) as long as the scrap price remains constant, and a (weak) negative relationship to the price of scrap. This means that, as P_f increases, secondary supply expands, increasing old scrap demand, and the increased price of old scrap in turn inhibits further output expansion.

The Interaction Between Primary and Secondary Copper

The analysis of the previous sections can be summarized briefly as follows.

- i Refined copper demand is fairly unresponsive to price changes in the short term, but quite responsive after one or two years. It appears nearly proportional to durable manufacturing activity.
- ii New scrap supply is highly related to the overall use of copper, but also appears to have some price responsiveness.
- iii The demand for scrap by secondary refiners appears to be related to the refiners' margin of refined over scrap prices, increasing when the margin widens.

- iv Old scrap supply appears quite price responsive even in the short term, allowing the secondary refiners' supply curve to be price responsive also.

These relationships of scrap and refined demand and supply to the various prices of copper in turn imply relationships between the prices themselves, and between the prices and the exogenous variables that drive copper demand in our simplified model. Beginning with the interrelationships of the important copper prices, figure 13 shows the COMEX and LME market prices to be virtually indistinguishable (indeed, they have been used synonymously in this report), and the refiners' buying price of scrap to follow the market refined prices allowing a margin for conversion. Before the freeing of the copper market in 1978, the producer price of copper followed the market prices sluggishly, responding to market pressures only with a lag.

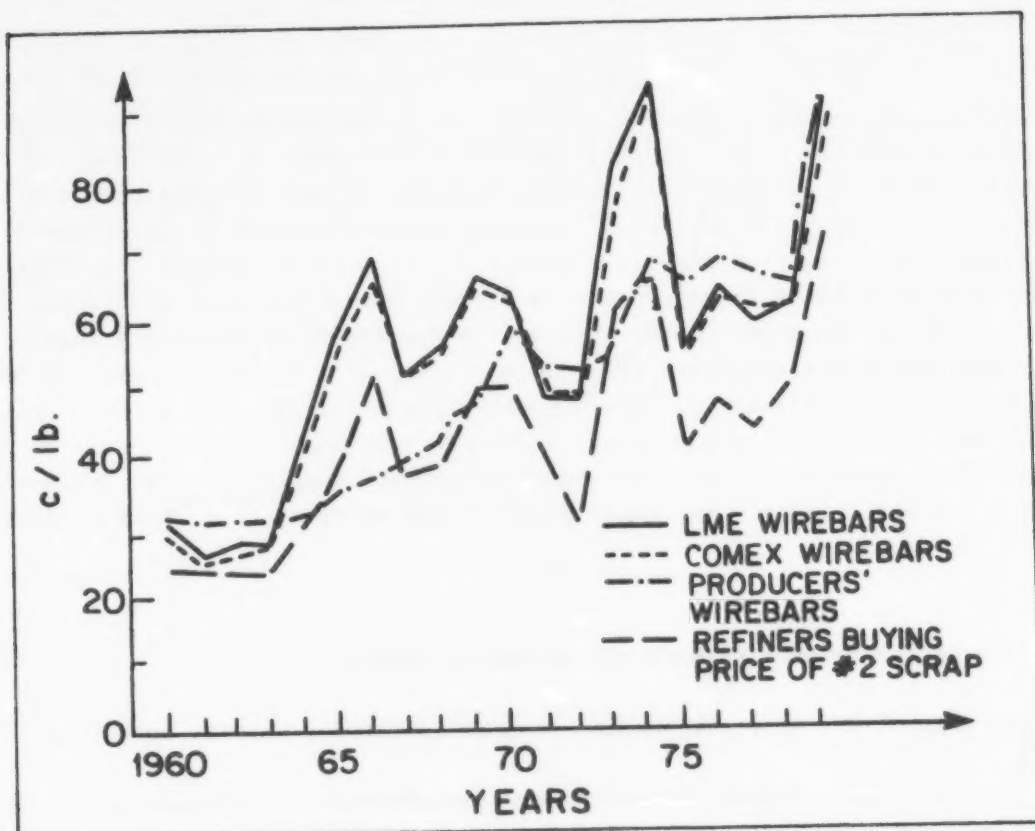


Figure 13. Trends in copper prices, 1960-79

While all the prices are determined simultaneously, the market prices (COMEX and LME) act as centrepieces of the market. The LME price itself is determined in the short run largely by demand conditions, as indicated by durable

manufacturing activity in the USA and Europe, as well as by unusual supply disruptions such as strikes and political activity.

In a regression shown in appendix II, the LME price was found to be strongly related to the U.S. index of durable manufacturing (Dur), and less strongly related to the grade of ore mined in the USA and to a dummy variable for U.S. export controls. Interestingly, Pf is much more weakly related to its lagged value than was found by Fisher et al., and has a lower coefficient, implying a faster speed of price adjustment in the 1970s and a freeing of the copper markets, perhaps reflecting the larger proportions of sales now taking place at LME (or COMEX) prices. By including only U.S. variables, however, the relation was almost certainly misspecified, since many international factors also influence the price.

Perhaps because of excluded variables, such as European manufacturing activity, we found that a 10 percent change in the U.S. durable goods index leads to a 12 percent increase in the LME price, reflecting the low response of supply to price changes in primary supply, the largest proportion of total copper supply.

Because we were unable to obtain the price of number 1 scrap, we relied on the assumption that it was highly correlated with the LME price. The number 2 scrap price was found to be statistically related to Pf, lagged old scrap supply, and the scrap export control dummy variable. It was found to vary in direct proportion to the COMEX or LME price (elasticity about unity) and thus indirectly with Dur, in a magnified fashion. This finding is consistent with the findings by Taylor and Slade (see table 13), both of whom found a strong relationship with durable production. The relationship with the supply of old scrap is more curious. Although the current scrap supply was found to be negatively related to its value in the previous year, reflecting the depletion of scrap stocks (as discussed above), the scrap price was also negatively related to $Ss_2(t-1)$. Other things being equal, it should be the reverse, since lower current supply should raise the price. The explanation must lie in the behaviour of secondary processors, who are perhaps adjusting inventories over more than a single year and lowering current purchases in response to higher-than-normal previous demand.

The producer price of refined copper adjusts as expected to the free market price. In estimating equation 15 at the beginning of this chapter we found a highly significant overall relationship and an adjustment coefficient of .52, implying that, on average, about half the difference between the producer price and the COMEX price was removed in a year. However, alternative formulations are plausible, depending on the degree of isolation assumed between the USA and the rest of the world. Hartman (1979), for example, determines Pp from

production costs without reference to the world market. Taylor estimates the Engineering and Mining Journal Price (of which the producer price receives 98 percent of the weight) as a function of a scrap price and finds a high correlation (this is not inconsistent since we have seen that P_{s2} and P_f are highly related). In general our formulation seems preferable in reflecting recent institutional changes making the U.S. market less insulated from world demand and supply.⁶⁷

An interesting question concerning the operation of the scrap market concerns the extent to which refiners' and scrap dealers' margins change with the overall state of the market for copper. As previously indicated in figure 8, the refiners' gross margin has exhibited considerable variability over the years. Is it related positively or negatively with overall copper demand? Since the major scrap dealers purchase unprocessed scrap from collectors and small dealers, they too work on a margin between their purchase price and the refiners' purchase price for processed scrap. Figure 14 plots the changes in refiners' and dealers' margins with the COMEX copper price.

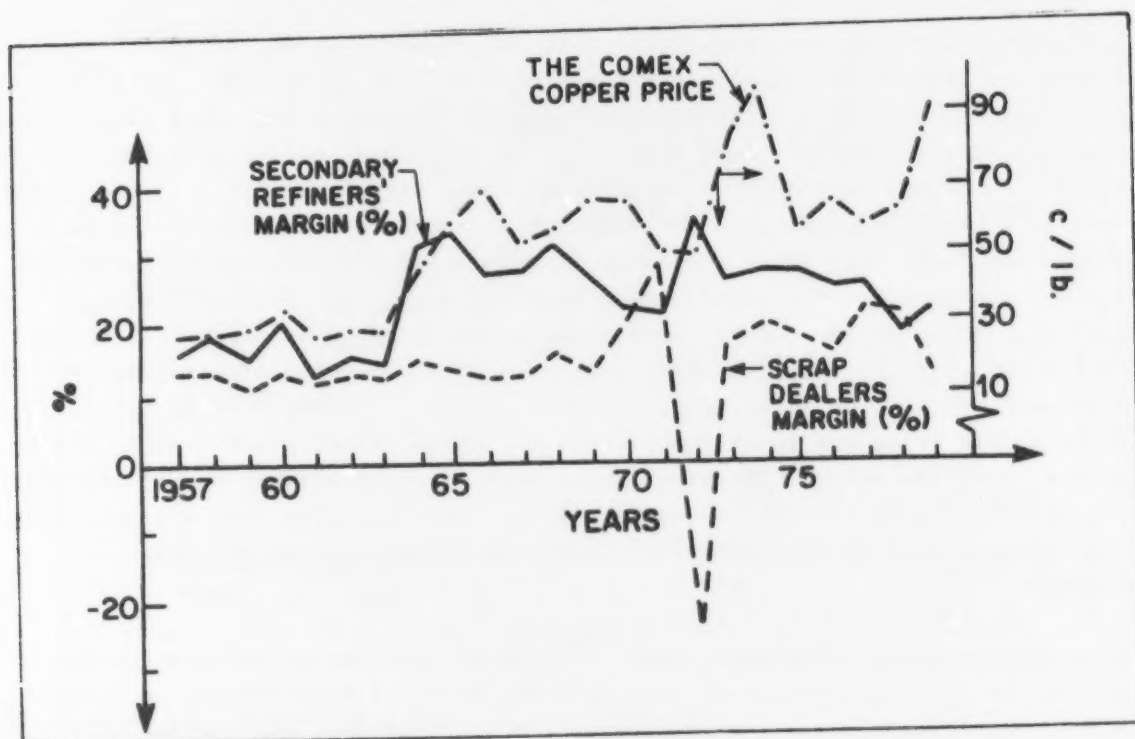


Figure 14. Scrap dealer and secondary refiner gross margins and the price of copper on COMEX

As is evident from the graph, there appears to have been a fairly good positive correlation between the secondary refiners' margin and the market price of copper over the years. This indicates that, although the refiners' buying price does rise with the market price as more scrap is demanded from dealers, (and the correlation is quite strong, as previously discussed), it rises not quite in proportion, allowing the refiners' margin to widen. This is consistent with the previously discussed finding that old scrap supply from dealers is highly responsive to scrap prices, resulting in enough supply appearing in the market to dampen the increase in the refiners' buying price. As shown in appendix II, the secondary refiners also appeared to have benefited from the administered pricing regime in the primary market and the associated scrap export controls introduced in 1964.

The dealer margin appears to have been much less variable in the 1950s and 1960s, the dealers participating little in the market boom in the last half of the 1960s, although statistically their margin is also positively related to Pf. There appears to have been a structural change in the 1970s, introducing much more variability in the margins of the larger dealers. The exaggerated negative response to the 1971-72 slump in terms of dealer margins is so far unexplained.

How U.S. and Canadian primary production is related to the price of scrap depends on the supply responses to the producer price in the two countries. In a formal sense there is no supply curve in the USA, as the U.S. producers do not respond to the producer price but set it; however, they may be expected to increase output and slowly adjust producer prices as demand increases, creating a positive correlation between output and price. Attempts to estimate this relationship have had mixed success. The Charles River Associates found no significant relationship between 1947 and 1967, while Fisher et al., using a similar sample period, calculated a short-term (yearly) supply elasticity of .45 and a long-term elasticity of 1.67. While the differences in the results can be accounted for by the difference in the equation specification, an estimate of U.S. primary response is difficult to determine. A regression relating the supply of primary refined output from ore to the producer price over our sample period estimated the supply elasticity as .23. Thus, an increase in durable goods production of 10 percent, while raising the LME price 12 percent and the scrap price about 13 percent, will increase the producer price on average by only 6 percent in the current year and increase U.S. refinery output by only 1.4 percent. In the long term, for a given ore grade the supply response could be expected to be considerably greater, except that the decline in ore grade reduces the long-run net elasticity of supply. Taking account of this factor, which was not considered by Fisher et al., would probably reduce even the long-run U.S. primary supply elasticity to below unity.

The Canadian overall supply elasticity is similar in magnitude to that in the USA, if not lower; but the elasticity of exports to the USA in response to U.S. producer price changes could possibly be a bit higher. This is not a contradiction, because the alternate Canadian producer option traditionally has been to sell in Europe at the LME price. The extent to which switching might occur when LME and U.S. producer prices differ would depend on institutional factors in the market. Two factors militate against such a response. Most copper is traded in long-term contracts, and within that time the producer price would be expected to adjust. Vertical integration in the copper industry and the relationship of refiners to fabricators (especially wire mills) would likely also inhibit rapid response to price.

The evidence on Canadian supply response to the U.S. market indicates that the elasticity is in fact very low. Fisher (see table 13) found a short-run elasticity of .188 and a very slow long-term response (only 2 percent of adjustments per year). Very few other estimates have been made.⁶⁸ A regression for this study (appendix II, equation 5) found no significant short-term response to U.S. producer price changes. Thus, like U.S. producers and because their output response is limited by technical and institutional factors, Canadian refiners are affected by the U.S. scrap market mainly through the effects of the scrap market on the prices of copper.

The Price Effects of the Scrap Market

The difference the scrap market makes in terms of the response of copper prices to an increase in demand as represented by increased durable manufacturing can be discussed by means of the general copper market model outlined at the beginning of the chapter. When this is simplified by including new scrap with refined copper as essentially the same material, the model becomes the following, with the explicit addition of copper imports, M_f , into the USA:

$$D_f(P_p, P_f, Dur) = S_p(P_p, g) + S_{s1}(P_f, D_f) + S_s(P_f, P_{s2}) + M_f(P_f, W_{Dur}) \quad (9)$$

$$D_{s2}(P_{s2}, P_f) = S_{s2}(P_{s2}, S_{s2}(t-1)) \quad (10)$$

$$P_p = \gamma (P_f/P_p - 1) \quad (11)$$

where for simplicity the aluminum price in the demand relation and the various costs of primary and secondary production, such as wages and energy costs, have been omitted. Suppose there is an increase in durable manufacturing in the USA and Europe (Dur and W_{Dur}). In the short term the producer price and S_p remain in constant, but P_f and P_{s2} will rise to clear the market. The extent of the increase in P_f depends in a complex way on the short-term elasticities of

supply and demand as shown in appendix II. We have seen that the average response from 1957 to 1979 of Pf to Dur was to increase by 123 percent of the change in Dur. What would have happened had scrap supply been unresponsive to increases in price or income? Based on the elasticities we have estimated, table 15 compares the average change in Pf due to a 10 percent change in Dur when:

- i new and old scrap are totally fixed in supply;
- ii new and old scrap are unresponsive to price, but new scrap increases with Df;
- iii old scrap only is price-inelastic.

According to these rough estimates, the response of scrap supply means that a 10 percent increase in durable manufacturing in the USA and Europe increases LME price by an average of 12.3 percent, instead of 15.7 percent without a scrap supply response, a difference of 3.4 percent. As shown in table 15, most of the scrap response is due to the increase in new scrap with increased copper fabrication. The absence of old scrap price responsiveness would affect the price by only .6 percent. This, of course, applies to changes only. The absence of scrap copper from the market altogether would remove 50 percent of total metallics and probably would double the price.

Table 15. EFFECTS OF SCRAP RESPONSIVENESS ON PRIMARY PRICE

Normal price response	1.23
Both new and old scrap inelastic	1.57
No price response:	
New scrap increases with Df only	1.36
Only old scrap inelastic	1.29

The Effects of Energy Prices, Ore Grade and Pollution Controls

Since secondary production is much less energy intensive than primary, there is a widely held belief that higher energy prices will automatically cause scrap metal to force primary metal out of the market. In fact, this presumption is in error, as energy prices affect the scrap market in a more complex fashion. While, as previously noted, scrap copper can use as little as 1/10th to 1/25th of the energy needed to process equivalent material from ores, secondary processors' costs are still significantly affected by energy prices. Slade (see

table 13) estimated the elasticity of processors' marginal costs with respect to energy as 21 percent, i.e. a one-dollar increase in her energy index (mostly electricity) increases marginal cost by .21, other things being equal. However, neither the primary or secondary price nor the share of scrap in consumption have tended to increase with energy prices.

The reason, discussed in chapter 4, is that demand as well as supply is affected. As energy prices increase, durable production declines, reducing the demand for both primary and secondary copper. Therefore, although all copper production costs increase, prices tend not to be significantly affected, as indicated by the absence of a significant effect of P_e on P_f in the appendix II equation. The recycling rate does not increase, for two reasons. As we have seen, changes in D_{ur} affect the scrap price more than the producer price. As well, the decline in copper demand reduces the stocks of scrap to be reclaimed, reducing old scrap supply. The net effect of these forces is to leave little incentive to substitute secondary for primary copper.

There is a tendency for the scrap metal share to rise, independent of energy prices, as a result of the declining grades of primary copper.⁶⁹ The average yield per ton of ore mined in the USA fell from .89 percent in 1950 to .49 percent in 1979. A similar decline would be expected to apply to Canadian ores. This reduction in grade affects primary processing costs very substantially, in fact increasing their energy intensiveness. Slade found declining grade to be equal in importance to wage increases in its effect on the primary (producer) price of copper, a 1 percent change in the yield (from .49 to .48 for example) having the effect of raising the primary price by 1.7 percent, other things being equal. Because declining grade is irreversible, this factor will result in initial substitution away from primary copper, then ultimately away from copper altogether because, as demand declines with increased price, scrap stocks and secondary production will decline.

Finally, existing and proposed emission controls have had and could continue to have a major impact on the copper market. The Environmental Protection Agency since 1970 has enacted water and air quality standards affecting all four stages of primary copper production (mining, milling, smelting, and refining), as well as secondary production to a lesser extent. The most important regulations were the Clean Air Act Amendments of 1970 and 1977 and the Federal Water Pollution Control Act Amendments of 1972. The Clean Air Act Amendments essentially established an ultimate emissions limit that was to have been achieved by 1988. Before that time, all new capacity was to conform to the Best Available Control Technology guidelines for permanent emissions reduction. The result of the regulations would have meant 'the capture of over 90 percent of the sulphur in the input to a smelter' and that 'gases from any new, reconstructed or modified

smelter be treated to recover 99.6 percent of the SO₂ in the gas stream.⁷⁰ According to data supplied in a study for the Economic Council of Canada, this would have meant the elimination of the 2.5 to 3 million tonnes of airborne sulphur dioxide emissions generated by U.S. nonferrous smelters.⁷¹ The study also documented significant cross-border transfers of pollution, giving Canada a strong interest in such abatement on the part of the USA.

The consequences of regulations such as these, however, are to increase the variable and fixed costs for primary producers and effectively constrain additions to capacity, because small, incremental smelter expansion cannot meet the standards and would be precluded. According to the simulation done by Hartman et al., the regulations would have raised unit operating costs by 2.5 cents per lb. (to 45.5). Depending on the severity of enforcement, this would have either constrained capacity at 2.37 million metric tonnes, or actually reduced it to 2.12 million metric tonnes for the primary producers.⁷² They estimate that by 1987 this would have raised producer prices by from 29 to 39 percent, reduced primary output by 25 to 33 percent, and increased copper imports by 16 to 21 percent. The difference between primary production and imports would have come from scrap, which would have increased by 17 to 23 percent in the two scenarios. While these estimates may be exaggerated by the estimating technique,⁷³ they give an indication of the impact such controls can have on copper. At the time of writing, the Secretary of the Interior under the Reagan administration has made it clear that these controls are unlikely to be fully implemented.

6. THE EMPIRICAL RELATIONSHIP OF FERROUS SCRAP TO PIG IRON AND IRON ORE IN STEELMAKING

Introduction

In a fashion parallel to the previous chapter, we here investigate the empirical relationship of ferrous scrap to pig iron and iron ore in the U.S. steel industry. The basic model we apply to the industry assumes that steelmakers employ both scrap and pig iron in steel furnaces in such a manner as to minimize production cost for a given steel output. This cost-minimizing behaviour implies substitution between the inputs of scrap, pig iron, and energy on the basis of their costs. A low price for scrap may induce a firm to substitute scrap either within a given furnace or between high-scrap and low-scrap furnaces, perhaps reducing pig iron production and, ultimately, ore demand.

The Canadian national interest is less clear-cut with reference to ferrous scrap usage and prices than in the case of copper scrap. Increased ferrous scrap usage may reduce employment in Canadian iron ore mines, to the extent that substitution does take place; this is analogous to the effects of scrap usage on copper producers. However, Canadian steel producers also use scrap which, in the case of both eastern and western electric furnace plants, is imported from the USA. The Canadian scrap metal dealers, on the other hand (who are mainly located in central Canada) are subject to U.S. scrap prices and clearly want these prices to be high. As the Canadian integrated producers in central Canada generally own iron ore mines, there is less conflict than one might suppose, but for the regional steel mills and the iron ore industry the conflict of interest persists. In what follows we shall be descriptive rather than prescriptive about the effects of the U.S. ferrous scrap market on Canada's ore market, and shall attempt to outline the extent of the trade-offs involved.

The first section of this chapter briefly summarizes the model discussed in chapter 4 to be applied to the U.S. steel industry. The second and third sections discuss estimates of the demand for ferrous scrap and supply of ferrous scrap, respectively. These estimates are integrated into a model of U.S. scrap, pig iron, and iron ore supply and demand in the fourth section, where we discuss the overall degree of substitution of iron ore and scrap.

The Structure of the Empirical Model

The model of the steel industry outlined in chapter 4 assumed steel prices to be exogenously given (a mark-up over average costs) and assumed demand for the output of U.S. steel producers to depend on general economic activity (a durable goods index, for example) and on steel imports. The steel and cast iron producers (the integrated steel mills, specialty electric steelmakers, and foundries) use pig iron and scrap in open hearth, basic oxygen, electric, or cupola furnaces to make the basic steels to be semi and then fully fabricated. Substitution between pig iron and scrap can take place either within a given type of furnace, subject to technical constraints on the use of scrap, or between furnaces, as different furnaces use different scrap proportions. Efficient cost minimization implies the use of metallics to the point where the steel price times the marginal product of scrap equals the scrap price.⁷⁴

($P_f MP_s = P_s$) and the marginal value of pig iron equals its marginal cost to the firm ($P_f MP_p = MC_p = MC_o/MP_o$), the latter equal to the marginal cost of ore divided by its marginal product. These conditions result in the system of scrap and pig iron demand and supply relationships described below:

Furnace Shares

$$D_{sj}/S_{fj} = f(P_s/P_f, S_{fj}) \quad (18)$$

$$D_{ij}/S_{fj} = g(MC_i/P_f, S_{fj}) \quad (19)$$

$$S_{fj}/S_f = h(P_s/P_f, MC_i/P_f, S_f, P_e/P_f, t) \quad (20)$$

where j = open hearth, basic oxygen electric and cupola furnaces

Total Scrap Demand and Supply

$$D_s = S_f \sum (D_{sf}/S_{fj}) (S_{fj}/S_f) \quad (21)$$

$$D_i = S_f \sum (D_{ij}/S_{fj}) (S_{fj}/S_f) \quad (22)$$

$$D_{sp} = D_s - SSh(S_f, t) = S_{sn} + S_{so} - S_{sx} \quad (23)$$

$$S_{sn} = S_{sn}(S_f) \quad (24)$$

$$S_{so} = S_{so}(P_s, P_e, A) \quad (25)$$

$$D_o = D_o(D_i) \quad (26)$$

First, the shares of scrap within a given furnace type, (D_{sj}/S_{fj}) depend on output and on the relative price of scrap to steel, for example. Similarly, if capacity is underutilized and furnaces have inherently different ratios of scrap to pig iron, the share of a given furnace type in total output (S_{fj}/S_f) may depend on relative prices. Changes in total scrap and pig iron demands (D_s and D_i) can thus result from changes in either within-furnace or between-furnace shares. Although the steel price is exogenously given, the model determines the

price of scrap (P_s) as the price that equates total purchased scrap demand (D_{sp}) from all furnaces (total scrap demand, D_s , less home scrap, SSh) with new and old scrap supply less scrap exports (equation 23). New scrap, of course, depends largely on total steel output (equation 24), while old scrap is responsive to changes in scrap prices, as well as scrap stocks, $A(t)$. Finally, the demand for ore is simply dependent on pig iron demand, as ore is the major input to the blast furnace.

Besides establishing the determinants of scrap prices and the relationship between scrap and iron ore, the model can be used to investigate the effects of changes in scrap export levels, changes in the price of electricity, or changes in the technology of steelmaking. An increase in scrap exports, S_{sx} , would be expected to increase scrap prices, and perhaps induce a switch to greater pig iron usage either within or between furnaces. Electricity price increases would, for example, disadvantage electric furnaces (using nearly 100 percent scrap) relative to the BOFs, which depend on pig iron heated with blast-furnace coke. The indirect result would likely be to lower the demand for scrap relative to pig iron and cause scrap prices to decline. The inclusion of a time index in the home scrap supply function is a means of taking account of technological changes such as continuous casting of steel, and of estimating their separate effects.

The following two sections form empirical estimates of the demands for scrap and pig iron represented by the general functions of equations (18) to (20), and the supply functions for new and old scrap, (24) and (25). These are then integrated in discussing the model's empirical implications.

The Demand for Ferrous Scrap and Pig Iron

How the share of scrap and pig iron within a given furnace, as well as the shares of a given type of steelmaking furnace in total output, can respond to changes in scrap steel prices depends on the technology of steelmaking. This technology has not been constant over the last three decades. The most important change in technology was represented by the replacement of the older open hearth by the basic oxygen furnace. In terms of our models this is represented by the effects of the time index in the furnace share equation (20). This innovation was not related to the prices of scrap and iron ore, but was motivated simply by the huge advantage in efficiency of the BOF over the OH, as it can be charged in a fraction of the time needed for the older furnace (U.S. integrated producers were in fact very slow to innovate in this regard, well behind European, Japanese, and Canadian steelmakers.) When the U.S. steelmakers did switch to the BOF, however, they did it rapidly, so that the BOF increased

its share of total production from 3.3 percent in 1960 to about 56 percent in 1979, while the open hearth fell from 87 percent to 14 percent in the same period. Because the two furnaces do the same job and the BOF is more efficient, there is no reason to doubt that the open hearth will eventually be phased out entirely.

The BOF employs a radically different technology from the open hearth furnace, and has a more limited tolerance of scrap. In the open hearth furnace almost any ratio of scrap to hot pig iron could be charged in the furnace, because the heat was produced externally; a higher proportion of cold scrap simply increased the heating time, although the degree of impurities also was important. The heat for the BOF is produced by an exothermic reaction of carbon in the pig iron from the blast furnace with a stream of pure oxygen fed into the BOF. Without a certain heat level to start the reaction (derived from the hot blast furnace pig iron), it cannot proceed. Therefore, there is, at present, a maximum upper limit of about 30 percent to the use of cold scrap in the furnace. When one considers that the overall scrap proportion was nearly 50 percent in 1960, it is clear that, other things being equal, the expansion of the BOF will both reduce the use of scrap as a proportion of steel production and limit the possibility of substitution of scrap for pig iron in response to changes in their prices. It has been estimated that the growth of the BOF, had other things been equal, would have reduced scrap demand by about 30 percent in the last decade.

These two trends created by the increased use of the BOF - the decline in scrap use and in the possibility of substitution of scrap for pig iron - have been at least partially offset by other developments in the industry. Partly in response to an increased demand for specialized alloy steels, and partly in order to utilize low cost-scrap no longer demanded by the BOF-utilizing carbon steel-makers, the use of electric furnaces has also expanded greatly. These are much smaller melting furnaces in which graphite electrodes heat the metal to the proper reacting temperature by producing a current through the metal itself. The electric furnace uses almost 100 percent scrap, and the rapid growth in use of this furnace has effectively counterbalanced the decline in scrap use caused by the BOF, keeping overall scrap use almost constant at about 45 percent of total metallics. The rise of the electric furnace also has provided an alternative means of utilizing scrap for an integrated mill with both BOF and electric capacity, since the electric furnace can also be used to make carbon steels. In periods of overall excess capacity, the technical limitations of both the electric and basic oxygen furnaces with regard to substitution of scrap and iron ore can be at least partially overcome by varying their relative utilization rates - shifting production between them, as well as between the BOF and the open hearth furnace.

It is not clear that the present 30 percent maximum for scrap use in the BOF will continue to be a strict limit in the future, if scrap prices decline drastically relative to the cost of hot metal. There are several experimental techniques for possibly increasing the use of scrap in this furnace. The two major contenders are the pre-heating of scrap before charging, by which means it has been estimated that the BOF could be made to accept up to 50 percent scrap, and the use of internal fuels, such as calcium carbide, possibly in conjunction with pre-heated oxygen. Of course, these new techniques all involve the introduction of an external energy source into the furnace, essentially the substitution of external energy for the heated pig iron, and may be more energy-intensive overall on balance. However, if the price of scrap declines far enough, relative to the cost of pig iron production, these new techniques will be further researched and utilized. While the growth of the BOF has surely reduced the elasticity of scrap demand, there is still room for substitution by varying the utilization rates of different furnaces as well as by extending the range of scrap employable in the BOF.⁷⁵

Besides the limitations imposed on scrap use by thermal efficiency, there are unwanted elements in ferrous scrap, called 'tramps', which must not be present in too great a concentration in carbon steel. The 'tramp' elements in ferrous scrap are mainly nonferrous metals, especially some that are neither driven off in flue gases nor collected in the slag, but remain in the steel. The four main groups of nonferrous metals in scrap are as follows.

- i Absorbed by the slag: silicon, aluminum, phosphorus, sulphur, and chromium.
- ii Distributed between the slag and metal: manganese, sulphur, and chromium.
- iii Remaining in the steel: copper, nickel, tin, molybdenum, cobalt, and tungsten.
- iv Vaporized up the flue: zinc, lead, and cadmium.

Their distribution depends primarily on the stability of the metal oxides and their ease of vaporization. The consequence of the distribution is that the content of copper, nickel, tin, etc. in group iii becomes an especially critical consideration. They may be desirable or undesirable depending on the grade of steel alloy intended, but for normal carbon steel they are major contaminants. With regard to the copper in steel, for example, the maximum desirable quantities in finished steels are:⁷⁶

<u>Grade of Steel</u>	<u>Percent of copper</u>
Low quality	0.5
Average quality	0.3
High quality	0.1
Deep drawing quality	0.05

If a particular grade of ferrous scrap is 0.5 percent copper, then for high quality steel the share of this scrap in the total metallics input cannot exceed 20 percent in order to meet the copper limitation. Similar constraints exist for nickel, tin, etc. in group iii, and sometimes for metals in the other groups as well. Zinc and lead, for instance, although removed during the steelmaking, can cause problems by clogging the tubes and checkers of the furnace.

The limitations on nonferrous metals in steels are, however, less of a constraint on total scrap use than on particular lower-grade scrap. So far in this chapter we have for simplicity ignored these grade differences. While there are many scrap types, in general six major classifications comprise the majority of scrap use, as described in chapter 3. These are number 1 heavy melting, number 1 bundles, number 2 heavy melting, number 2 bundles, turnings, and shredded scrap. Turnings and number 1 bundles are prompt scrap, as well as some number 1 heavy melting. Old scrap comprises some number 1 heavy melting, the other number 2 grades, and shredded scrap. Table 16 shows the purchases and home scrap generation for the major scrap grades in the U.S. steel industry. Home scrap comprises 53 percent of the total.

The differences in scrap grade lie in their different 'tramp' contents. As can be seen in table 16, the number 1 bundle has a much lower nonferrous metal content than, say, the number 2 bundle from scrap automobiles, and thus is higher quality and in much greater demand. In addition, it is of a known composition, coming from prompt industrial sources. Shredded scrap is an anomaly because in the shredding process nonferrous metals can be removed from automobile scrap, in effect making scrap of obsolete origin almost equivalent to number 1 heavy

Table 16. PURCHASES AND HOME SCRAP ARISING BY SCRAP GRADE, 1979.
(1000 short tons)

Scrap Type	Purchases	Arisings	Total
No. 1 heavy melting	8477	18005	26482
No. 2 heavy melting	2612	1513	4125
No. 1 bundle	7018	3012	10030
No. 2 bundle	2679	68	2747
Turnings	2045	462	2507
Shredded	3305	41	3346
Other	3371	11740	15111
Total	29507	34841	64368

Source: U.S. Bureau of Mines, Minerals Yearbook, 1979.

Table 17. SCRAP IMPURITY CONTENTS
(percent)

	Cu	Sn	Ni	Mo	S	Cr
No. 1 factory bundles	.06	.005	.04	.03	.025	.04
No. 1 industrial h.m.	.10	.01	.05	.03	.035	.04
No. 1 dealer bundles	.12	.016	.06	.03	.04	.05
No. 2 dealer h.m.	.40	.03	.20	.03	.08	.10
No. 2 dealer bundles	.48	.06	.09	.03	.10	.06
Shredded scrap	.22	.025	.10	.02	.03	.16

Source: W. Regen et al., Identification of Opportunities for Increased Recycling of Ferrous Solid Waste, (Washington: ISIS, 1972) p. 91.

melting in quality. A recent innovation in the scrap industry, shredding has greatly enhanced the value of obsolete scrap and resulted in a quantum increase in its demand. Insignificant in quantity before 1968, in 1979 shredded scrap supply at 3.3 million short tons exceeded that of the number 2 bundle.

As well as chemical composition, the size and density of scrap pieces also are limiting factors in scrap use. The scrap must be small enough to fit into the charging boxes, and must be cut to size. There is also an optimum scrap density. The heaviest forms of scrap are number 1 and number 2 heavy melting scrap, with bundles and turnings following in descending order. Consequently, density requirements also affect the type of scrap demanded. If density is too high, it increases melting time and leads to increased use of energy. If it is too low, it increases oxidation of the scrap, with resulting metal losses; it also extends production time because the scrap must be introduced in greater volumes and in several portions to offset oxidation loss. The significance of these factors varies with different types of furnaces; open hearth furnaces for example may use quite variable proportions and densities of scrap, while electric furnaces require optimum density scrap.

Because of these technical limitations on scrap use, especially in BOF furnaces, we would expect quite a low short-term elasticity of scrap demand. Only the obsolete open hearth furnace possesses significant flexibility of scrap/pig-iron ratios. While the replacement of the number 2 bundle with shredded scrap may have increased the overall demand for scrap somewhat, most of the response of scrap demand to price now comes from varying the shares of the BOF and electric furnaces, rather than from changes in the scrap/pig-iron ratio within a given furnace.

This was confirmed by estimating regressions for the ratios of scrap use to steel produced in open hearth, BOF, and electric furnaces yearly from 1958 to

1979 as functions of the relative price of scrap to steel.⁷⁷ Not even in the open hearth furnace was the relationship between scrap use and the relative price of scrap statistically significant. Instead, most of the changes in the within-furnace scrap ratios were related to the level of furnace output. In the case of the OH and electric furnace, increased furnace output caused the scrap ratio to decline. This finding is probably the result of the increasing importance of the technical factors limiting scrap, as overall steel output and scrap demand increase. Because the better scrap grades are used first, as output approaches capacity and lower grades must be utilized, the increased presence of 'tramp' elements forces a lower proportion of scrap in the steel.

A second factor which might account for a negative relationship of scrap shares to output is the negative relationship of output to the cost of pig iron due to scale economies in the blast furnace. Although the real cost of pig iron in an integrated mill is not a market but a transfer price within the establishment, the price of merchant pig iron published by the American Metal Market was strongly negatively correlated with the total steel output. If the internal pig iron cost were statistically related to the merchant pig iron price, this would be an indication that substitution was taking place on this basis. Replacing steel output by the merchant pig iron price in the regression did not result in an improved specification, however, even in the OH furnace. Thus it appears that within-furnace scrap demand is insensitive to price.

The shares of the different furnaces in total steel output are more responsive to scrap prices. A 1-percent increase in the relative price of scrap raised the BOF share an average of .2 percent (this is a furnace with relatively less scrap use), and lowered the OH and electric shares correspondingly. While integrated mills usually have some electric furnace capacity, for the most part electric furnace mini-mills and integrated mills are independent and competing in both the steel and scrap markets. Thus it is likely that in a tight scrap market the smaller less-established mills are at a competitive disadvantage relative to the integrated steelmakers in their purchases of scrap.

The overall elasticity of total scrap demand is a weighted average of changes in the furnace shares, and was estimated at $-.20$. The different furnace shares are also strongly related to total steel output, as shown in appendix III. The BOF and OH furnace share increase with total steel, while the electric furnace share declines (after the exogenous trend has been removed). This, apparently, does seem to be the result of pig iron scale economies, since, when the merchant pig iron price is substituted for total steel, it is significant in these regressions. The elasticity of total scrap use with respect to steel output was calculated at $.87$.

These overall scrap demand elasticities can be compared with those estimated in several previous studies, shown in table 18. These estimates range from zero for monthly price changes to -3.0 over several years. With the exception of Shriner, who did some estimation on an individual furnace basis, all the estimates are of either aggregate purchased scrap demand or of scrap segregated by type. Our estimates fall in the intermediate range.

Table 18. SUMMARY OF FERROUS SCRAP DEMAND ELASTICITY ESTIMATES

Source	Scrap Type	Own Price	Steel	Sample
Adams	no. 1 h.m.	-.62		monthly
Adams	no. 2 bundles	-.20		monthly
Anderson	all grades	-.64	1.1	monthly
Environmental Law Institute	all grades	-.62		monthly 1961-72
Environmental Law Institute	no. 2 bundles	0		monthly
Nathan Assoc.	all grades	0		quarterly 1961-76
Shriner	all grades	0 (s.r.) -3.0 (l.r.)	1.0	yearly
Stollery	all grades	-.2322	.669	yearly 1959-79

Sources: R.L. Adams, 'An Econometric Analysis of the Junk Auto Problem,' Ph.D. dissertation, Univ. of Illinois, 1972, chapter 4; P.C. Anderson, 'Tax Policy and Secondary Materials Use,' Journal of Environmental Economics and Management, 4, 1977; R. Anderson et al., Federal Tax Policy and Depletable Resources, Environmental Law Institute, 1972; Nathan Associates, 'Price Volume Relationships for the Supply of Scrap Iron and Steel', in U.S. Export Control Policy and the Extension of the Export Administration Act, GPO, ASI-79, 1979; R.D. Shriner, 'An Econometric Analysis of the Demand and Supply of Scrap Iron and Steel', Ph.D. dissertation, University of Indiana, 1974.

Given these estimates, there does appear to be some substitution between scrap and pig iron in U.S. steelmaking and ferrous foundry plants. However, this substitution seems to take the form of changes in the relative furnace share reflecting the changing competitive positions of the integrated versus electric

mini-mills, rather than changes in the ratio of scrap to pig iron within a given furnace.

Probably as a result of blast furnace scale economies, scrap demand expands less than proportionally with total steel output, other things being equal, and pig iron proportionally more. Although perhaps not representative of the hot pig iron costs, the merchant pig iron price was strongly negatively related to total steel output, and total pig iron use was itself negatively related to this price, with an elasticity of $-.645$. Canadian ore demand in the U.S. market tends to be more than proportionally related to total iron demand with an elasticity of 1.424 , but not significantly related to the Lake Erie pellet price. For total steel output, the elasticity of ore demand was 1.726 . How the scrap price, the merchant iron price, and the price of ore change with steel output depends on scrap supply.

The Supply of Ferrous Scrap

Home and New Scrap Generation

Home scrap generation depends, of course, on total steel generation, but the proportion has varied over the years. It increased from 1950 to 1970, mainly as the result of declining ingot-to-ship yields (steelmaking efficiency) in U.S. mills. Finished steel yields declined from 74.2 percent of raw steel to 68 percent over the period and the home scrap proportion of finished steel rose from 25.6 percent of raw steel to 32 percent.⁷⁸ The main reason was the increased demand for higher steel quality resulting in lower yields, intensified by a changing product mix toward lighter, flat-rolled products and away from heavy steel, causing a need for increased quality control. Flat-rolled product share increased to 47 percent in 1970 from only 35 percent in 1950.

Since 1970, however, this situation has been reversed by the wholesale introduction of a revolutionary process called continuous casting. Unlike the traditional method of pouring the molten steel into ingot molds for cooling, this process employs an open-ended mold; molten steel is poured into one end and drawn solid from the other. This greatly increases casting efficiency and lowers home scrap generation because it removes the need for cropping the ingots. Although the increased efficiency means that less raw steel is needed for a given volume of finished steel, thus reducing total scrap requirements, the disproportionate decrease in home scrap resulting from this process would be expected to create an absolute increase in purchased scrap demand. Compared with home scrap generation of 32 percent in 1970, the percentage for 1979 (shown in figure 15) was only 28 percent. The proportion of home in total scrap will

continue to fall until the continuous process completely replaces conventional casting.

The price of scrap also can affect home scrap generation. The higher the scrap price, the greater the incentive for efficiency of a fabricating operation where scrap is a major raw material input. Thus an increase in price can actually lower scrap generation. A regression of home scrap against total steel, a trend variable, and the price of scrap gave an elasticity of 1.1234 with total steel, an exogenous falling trend of .76 percent on average, and a scrap price elasticity of $-.107$.

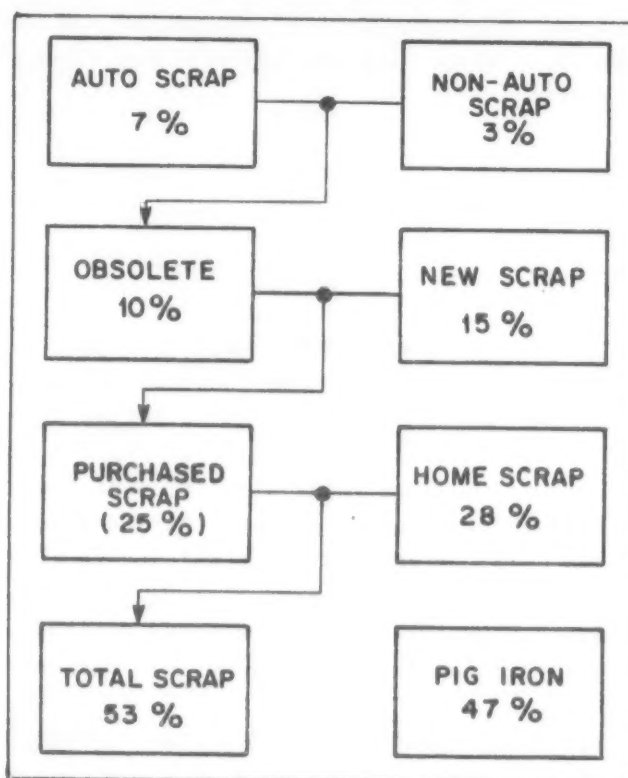


Figure 15. Shares of scrap types in steel-making in 1979

Of the total supply of purchased ferrous scrap, up to 60 percent is currently derived from prompt industrial sources, an increase from about 40-45 percent in 1955. The new scrap share is actually a controversial figure among analysts of the market, since published statistics are very unreliable. Original data supplied by the U.S. Department of Commerce in a study performed in 1966 indicated that the new scrap share of total purchased scrap was about 40 percent in 1964

(about 7 percent of total metallic feed), with no reason given to cause one to expect drastic change over time.⁷⁹ In contrast, a subsequent report by the Battelle Institute for ISIS in 1972 concluded that new scrap was closer to 60 percent of total purchased scrap. Their estimates were based on an extensive survey both of scrap users and of processors, and are supported by more recent research.⁸⁰ We shall adhere, therefore, to the revised 60 percent figure.

The relationship of new steel scrap to steel consumption in different industries was first studied by the U.S. Department of Commerce in 1957 with statistics collected for the U.S. Census of Manufacturers in 1954. The Department of Commerce analysis was based on the premise that the ratio of scrap arisings to steel input was constant for each industry and independent of the price of scrap. For the same reasons discussed in connection with new copper scrap, the assumption of zero supply elasticity is likely to be a reasonable approximation. The average new scrap generation ratio for all steel-using industries in 1954 was 17.5 percent, meaning that 17.5 tons of scrap were generated for every 100 tons of steel consumed.⁸¹ However, the past two decades have witnessed increased efficiency among iron and steel consumers and changes in the relative importance of the industries making up the survey. An updated report by Hogan and Koebler⁸² for 1954-74 concluded that these factors caused the new scrap generation factors to fall to 16.6 percent from 18.5 percent for foundry products. A comparison of the ratios in 1954 and 1974 (table 19) indicates a slowly falling trend in overall new scrap generation per ton of ferrous product consumption. However, a regression performed over the period 1959-79 found little statistical significance to the falling trend, the 't value' of the trend coefficient being 1.7. Furthermore, the regression also found no evidence of a response to the price of scrap, new scrap output being simply proportional to steel output with a coefficient of 1.158.

The Supply of Obsolete Ferrous Scrap

Like old copper scrap, ferrous scrap from obsolete sources depends on the reservoir of discarded products, in this case primarily the junk automobile⁸³ which is first stripped of useful parts by the auto wrecker before shipping to the scrap dealer.⁸⁴ Consequently, the auto salvage industry has been the one most often analyzed by researchers in attempts to estimate elasticities of supply for shredded and bundled scrap. One of the reasons for the concentration on auto-derived scrap is the fact that discard rates for automobiles can be fairly accurately determined, as cars are deregistered when junked. This information is published annually by the Motor Vehicle Manufacturers Association and allows one to estimate the probability that a car will be discarded n years after sale. Knowledge of auto purchases then allows one to predict deregistrations and changes in the pool of available future scrap. Table 20 shows levels of

Table 19. AGGREGATE PROMPT INDUSTRIAL STEEL SCRAP GENERATION, 1954 and 1974
(as percent of ferrous product consumption)

Market	1954	1974
Converting and processing	17.5	15.9
Forging	25.7	25.0
Industrial fasteners	29.3	19.6
Service centres	15.9	18.0
Construction	7.0	6.0
Contractors' products	11.8	9.1
Automotive	30.9	30.9
Railroads	7.1	7.8
Shipbuilding	25.9	13.8
Aircraft	31.6	25.0
Oil and gas drilling	12.2	16.7
Extractive industries	14.0	16.0
Agriculture	15.8	8.9
Machinery	21.8	19.2
Electrical machinery	26.5	21.8
Appliances	22.4	19.4
Domestic and commercial equipment	16.6	13.5
Containers	11.6	9.5
Ordinance	25.0	22.0
Total steel	17.5	16.6
Total foundry	18.5	16.9

Table 20. NORTH AMERICAN VEHICLE PURCHASE AND SCRAPPAGE RATES AND STOCKS OF VEHICLES IN USE, 1970-80
(millions of cars and trucks)

Year	USA				Canada		
	Purchases	Scrappage	Stock	Age of Stock (years)	Purchases	Scrappage	Stock
1970	8.4	8.3	139.9	5.5	.8	.6	8.1
1971	10.3	7.1	140.0	5.7	.9	.6	8.4
1972	11.0	8.1	143.2	5.7	1.1	.6	8.9
1973	11.4	9.2	146.1	5.7	1.2	.7	9.5
1974	8.9	8.2	148.3	5.7	1.3	.6	10.1
1975	8.6	6.5	149.0	6.0	1.3	.5	10.9
1976	10.1	7.9	151.0	6.2	1.3	.7	11.5
1977	11.2	9.9	153.3	6.2	1.3	.9	11.9
1978	11.3	9.3	154.6	6.3	1.4	.9	12.4
1979	10.7	11.2	154.1	6.4	1.4	1.1	12.8
1980	8.9	10.1	152.9	6.6	1.3	1.0	13.1

Source: Motor Vehicle Manufacturers Association, Motor Vehicle Facts and Figures, 1981. Canadian scrappage rate estimated.

sales and deregistrations in the U.S. and Canada from 1970 to 1980. Sales expanded fairly rapidly until the 1973 energy crisis, and consequently scrappage also increased, with a lag of 5-6 years. The three-pronged malaise of the auto market in the 1970s - unemployment coupled with inflation of both energy and auto prices - stopped the expansion in sales, increased the average auto lifetime from 5.5 to 6.6 years, and in the USA by 1978-80 created an approximately constant stock of vehicles in use. The result, unless sales increase dramatically during or after 1983, must be to slow the increase in the pool of available scrap and leave it approximately constant in the last half of the 1980s.

A second factor tending to slow the increase in potential ferrous scrap is the decline in vehicle weight, in the interest of energy conservation. General Motors has estimated that average shipping weight has gone down to 3230 pounds in 1980 from 3890 in 1975, and is projected to go to 2730 pounds in 1985. The iron in an average car, over 500 pounds in 1969 and 1975, will be only 300 pounds by 1985. Steel weight, over 2500 pounds in 1969, was 1900 pounds in 1980 and is projected to fall to 1600 pounds by 1985. On the other hand, aluminum usage will increase to 145-200 pounds and plastic to nearly 300 pounds. Table 21 compares the composition of typical 1969 and 1985 automobiles.

Table 21. CHANGE IN AUTO COMPOSITION, 1969-85

	Pounds		Percent		Percent Change
	1969	1985	1969	1985	
Steel	2530	1600	70.8	58.6	-36.8
Iron	511	300	14.3	11.0	-41.3
Aluminum	51	175	1.4	6.4	243.1
Other nonferrous	106	55	3.0	2.0	-48.1
Plastics	127	300	3.6	11.0	136.2
Other	248	300	6.9	11.0	20.9
Total weight	3575	2730	100.0	100.0	-23.6

Sources: Dean, K.C., and J.W. Steiner, Dismantling a Typical Junk Automobile to Produce Quality Scrap, U.S. Bureau of Mines Report of Investigations 7350, (Washington: U.S. Department of the Interior, 1969), p. 7; and 'Plastic Parts Help Car Lose Weight', Financial Post, December 20, 1980.

The relationship between old scrap supply and price has been studied by several researchers, with varying methods and results. Adams,⁸⁵ using monthly time series data from 1963-71, derived linear supply equations for both bundled and

shredded scrap, finding very high short-term elasticities of 8.0 and 10, respectively, during the period. Similar estimates have been made by Sawyer, using instead of regression analysis a linear programming model of a shredder and baler with costs and prices in the Philadelphia region in 1974.⁸⁶ Neither of these studies, however, took account of the effects of the depletion of scrap stocks on obsolete supply. This is a very important source of error, as evidenced by the dramatic increase in scrap prices in 1973 and 1974 when scrap stocks became short.⁸⁷ Studies using yearly data have resulted in much lower estimates of price response. The U.S. Bureau of Mines, Nathan Associates, and Arthur Little Inc., made elasticity estimates of 1.0, .83, and .63, respectively, with Anderson coming up with an intermediate figure of 8. An estimate made using yearly data and an explicitly generated stock variable (shown in appendix III) resulted in an elasticity over one year of .59, and a long-term elasticity of only .08. The estimates are summarized in table 22, below:

Table 22. OBSOLETE SCRAP ELASTICITY ESTIMATES

Sources	Price Elasticity
Adams	8.00
Sawyer	10.00
Anderson	2.80
Bureau of Mines	1.00
Nathan Associates	.83
Arthur Little Inc.	1.63
Stollery	.59

Sources: R. L. Adams, 'An Economic Analysis of the Junk Auto Problem'; Sawyer, 'Automotive Scrap Recycling'; Anderson, 'Tax Policy and Secondary Materials Use'; Bureau of Mines, Auto Disposal, a National Problem, pp. 67-70; Nathan Associates, 'Price Volume Relationship for Supply of Scrap Iron and Steel'; A. Little Associates, 'A Technoeconomic Policy Model of the Ferrous Scrap Industry,' Business Economics, May, 1980.

The estimates of old-supply elasticity, like demand responsiveness, are important because, reflecting the extent to which scrap can respond to increased price, they determine how much scrap prices rise when steel demand increases and to what extent there is an incentive to reduce scrap consumption. Because new scrap is insensitive to price increases, and home scrap generation actually declines as prices rise, an increase in scrap demand is felt entirely by obsolete scrap. As long as scrap stocks are sufficient, dealer supply can increase enough to supply the market, but when stocks become depleted, as in

1973-74, the result can be very large swings in scrap prices, which can spill over to iron ore prices as well. We shall look at these interactions next.

The Relationship of Scrap and Iron Ore

With the estimated relationships of the demand for pig iron and scrap, and the supply of scrap from home, new, and obsolete sources, the model can predict the differential effects of exogenous changes in total steel output, coal or electricity prices, scrap exports, or technological changes (such as continuous casting) on the demand for scrap and iron ore and on the average prices of scrap, merchant pig iron, or iron ore in lower lake ports.⁸⁸

We shall first look at the behaviour of prices. Figure 16 shows the prices of scrap, cold merchant pig iron, and iron ore from 1958 to 1979. The most striking aspect of these price movements is their behaviour in 1973-74, when, like copper and most other minerals, a virtual explosion took place. What caused this price explosion? As with other metals, it appears to have been the combination of unprecedented demand and an increase in costs of other raw materials

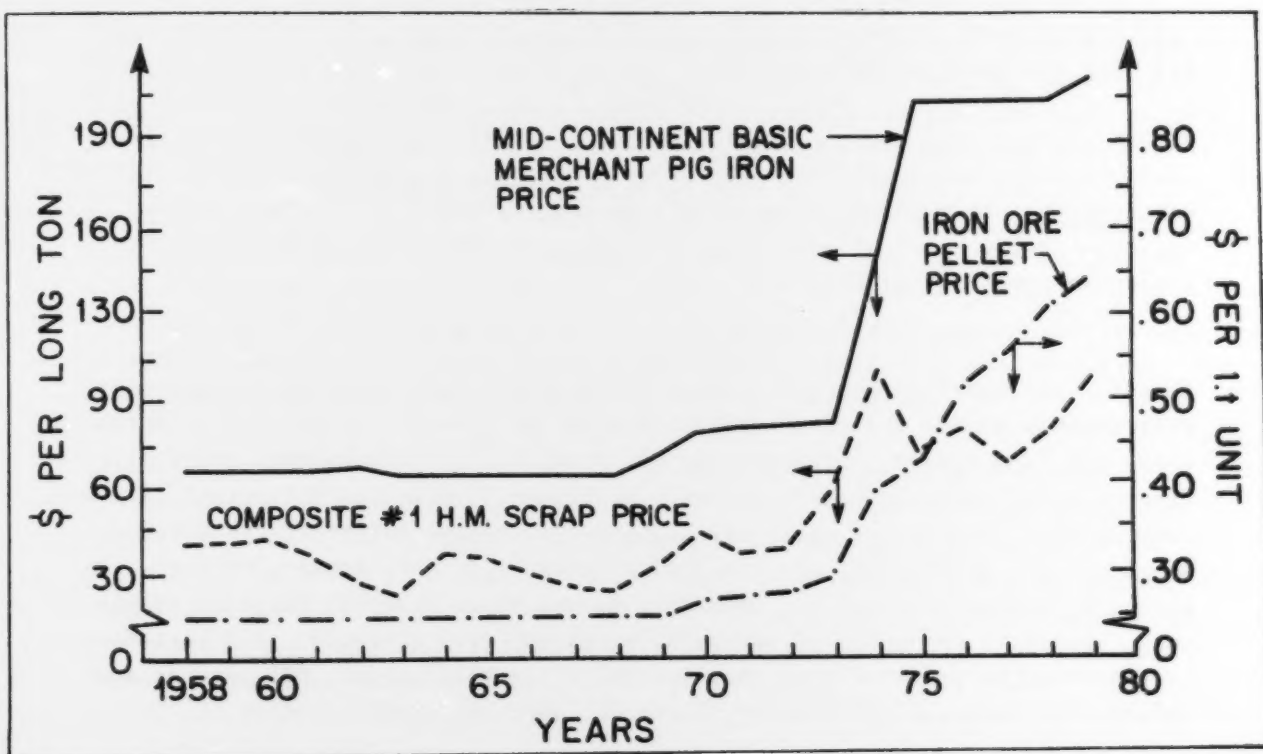


Figure 16. Scrap and iron ore prices, 1958-79

such as coal, coupled in the case of scrap with tight stocks of obsolete material. Regressions of the prices of scrap, pig iron, and ore (shown in appendix III) indicate a strong positive relationship between scrap and pig iron prices and the cost of coal in U.S. blast furnace operations; a direct relationship in the case of pig iron, and indirect for scrap, the increased cost of hot iron causing more scrap demand. When total steel output increases, the price of scrap increases as supplies become short, but the price of merchant pig iron (and surely also of intra-firm hot iron) decreases, because the continuously-running blast furnace can be utilized efficiently. This effect is very strong: a 1-percent increase in steel output reduces the price of pig iron relative to scrap by over 2.5 percent. Independent of these opposite relationships to steel output, the market pig iron and scrap prices are positively related, scrap price increases causing increased use of pig iron by foundries and increases in its price.

The Lake Erie base iron ore (pellet) price was found not to be related to steel output and to be only weakly related to the price of scrap. This is not surprising as this price is really not market-determined. The market may have more influence on the prices of natural ores in the USA, as they seem to be related to:

- i total pig iron outputs;
- ii the relative price of scrap;
- iii the previous year's ore price.

For this price, the elasticity with respect to U.S. pig iron output was .172, and with total steel .208 over the 1959-79 period. A 1-percent increase in the scrap price, other things being equal, was associated with a .128 percent increase in the price of iron ore, presumably as the result of increased ore demand in substituting away from scrap.

Canadian ore sales in the U.S. market appear to be affected, not through the relationship of ore and scrap prices, but rather through the effects of scrap on total pig iron demand. Although ore and scrap prices are somewhat related, Canadian ore demand appears to be only weakly related to the ore prices in lower lake ports. This is not surprising, given the captive nature of the North American iron ore market, as discussed in chapter 3. Ore demand, however, is strongly related to total pig iron use, as one would expect. Pig iron use is in turn related to the price of scrap, although not very strongly. A 1-percent increase in the price of scrap has increased pig iron output .085 percent and, indirectly, Canadian ore demand .12 percent over the period studied.

We can now get an idea of the magnitude of the effects of the U.S. scrap market on Canada. Canada exports about 25.5 million metric tonnes of iron ore to the United States, and both imports and exports about 1 million tonnes of scrap, our trade being approximately balanced in that commodity. Since a 1 percent increase in the price of number 1 scrap steel in the USA on average increases ore demand by .12 percent but does not significantly affect the pellet price, at least in the short term, we can expect export revenue to rise by about the same percentage. With iron ore exports of approximately \$770 million in 1979, this represents a boost of \$.9 million for every 1 percent change in the price of scrap. The fact that scrap imports become more expensive is counterbalanced, from the point of view of the whole economy, by the fact that scrap export prices would also rise to keep the scrap trade in balance. The distribution effects of scrap price increases within the country are, of course, to disadvantage Canadian steel companies which are not self-sufficient in ore, since they must pay higher prices for both ore and scrap.

Factors Affecting Future Scrap-Iron Relationships

Direct Reduced Ore and the Scrap Market

There has been considerable discussion within the steel industry recently concerning the possible implications for the demand for ferrous scrap of several techniques that now appear to be commercially feasible for the reduction of iron ore directly to pig iron. These techniques permit direct reduction, in which iron ores or oxides bypass the intermediate step of making hot pig iron in a blast furnace. Direct-reduced ores, unlike conventional iron ores (hematite or some other iron oxide), are already equivalent to pig iron and can be charged cold directly into the steel furnace. While in a sense they can substitute for both hot pig iron and scrap in a steel furnace, their main application has been in the electric steel furnace (which conventionally uses only scrap). Thus direct reduction effectively substitutes iron ore for scrap.

Literally hundreds of direct-reduction methods for producing sponge iron or similar products have been patented over the years. Indeed, direct-reduction processes go back many centuries. Interest in these processes has waxed and waned with the price of scrap, but only recently has direct reduction become competitive with scrap and the cost of blast-furnace pig iron. The reason for the interest in the direct-reduction alternative has to do with the disadvantages of the blast furnace:⁸⁹

- i it must be huge to be economical - up to 12,000 tons per day capacity - so its use is restricted to large integrated steel plants, such as Stelco's facility which produces 4000 tons/day;
- ii such large blast furnace capacity is extremely expensive to build and equip - at least \$50 million for a single facility;
- iii high-quality metallurgical coke is required as part of the process;
- iv fine concentrates cannot be handled directly, but must be sintered, pelletized, or briquetted before charging into the furnace;
- v low-grade iron ores are not handled very well, nor those high in silicon or titanium.

The main advantage of the blast furnace has been that until now the price of coke has been low enough to keep the cost of hot blast-furnace pig iron below that from any competitive process. However, from 1972 to 1979 the price of purchased metallurgical coal for coke in the USA rose over 250 percent. Although coal from captive mines owned by the integrated steel companies only increased 110 percent (and 2/3 of U.S. steelmill coal is from captive mines), this meant an average increase in coal costs of nearly 140 percent over the intervening years.⁹⁰ The main reason was a very large increase in mine labour costs, especially between 1974 and 1976, reflecting a 30 percent increase in wages coupled with a 25 percent decline in productivity due to new mine safety regulations. The resulting increased coke prices have reduced the blast furnace cost advantage very significantly.

Direct reduction produces iron without coke. It can use a much smaller, more versatile furnace (as low as 50 tons per day capacity) which can be either electric, coal fired, or fueled by natural gas. Consequently, direct-reduction capacity has been expanding in countries that are relatively energy-rich in either electricity or natural gas, giving such countries an opportunity to build a less capital-intensive steel industry. New capacity is being installed by Indonesia in the Far East; by Iran in the Middle East; by Venezuela, Mexico, and Brazil in Latin America; and by Canada in North America. Currently, Canada is second only to Mexico in installed capacity, with 1.7 million tons. Because direct-reduced iron is low in carbon (2 percent C maximum as opposed to 4 percent in pig iron), it is admirably suited as a feedstock for low-carbon alloy steels produced by the electric-arc steel furnace.

In Canada there are currently four operational facilities, as well as two pilot plants, in Niagara Falls and Hamilton. Most of Canadian capacity uses the midrex process employing natural gas; most output, with the exception of the Sudbury metals facility that exports to the United States, is expected to be used in Canada. As this also is the case for most of the projected direct-reduced output in other countries and areas (table 23), the result will not be

substitution of direct-reduced ores for scrap directly in the U.S. market, but a decrease in the demand for scrap exported from the USA to these regions, which will indirectly free U.S. generated scrap for domestic use. Direct reduction may thus indirectly increase the supply of ferrous scrap in the United States, relative to the demand, while reducing scrap demand directly elsewhere.

Although the technique is important in the individual countries, the reported figures indicate that direct reduction is not likely to make much of an impact on the U.S. scrap market through 1982. The production of direct-reduced ore in U.S. scrap export markets forecast by Hogan and Koeble in table 23, based on a survey of facilities, is only 13 percent of their projected purchased scrap demand of 170 million tons in those countries; and, when account is taken of projected trade within the export markets, the substitution for U.S. scrap exports is only 15.5 million tons. While U.S. scrap exports in the 1970s were on average only 9 million tons (representing about 8 percent of total scrap consumption, but 35 percent of purchased scrap), the expansion of direct reduction is not likely to completely replace these exports and force down the U.S. price of scrap, because all but about 9 percent of the 170-million-ton foreign scrap demand will come from internal sources or from other countries with developed scrap industries. It is estimated that by 1982 direct reduction will have reduced U.S. scrap exports by only about 9 percent, relative to what they would have been, and will have diverted about 2 million extra tons of ferrous scrap into the U.S. domestic scrap markets. This amounts to an increase in domestic purchased scrap supply of only about 8 percent as a result of direct reduction, not enough to have a significant impact on U.S. scrap prices or on the demand for traditional pig iron (and iron ore) by the integrated steelmakers with installed blast furnace capacity, at least not in the short term. In the longer term, however, the enhanced saleability of direct reduced ores might be offset somewhat by these reduced scrap prices.

U.S. Legislation Affecting Scrap Supply

Since the late 1960s, increased attention has been paid in U.S. political circles to the so-called 'discrimination' of federal tax policy, railroad freight rates, and federal procurement policies against scrap 'recyclers' and in favour of primary producers. This discrimination was alleged to artificially discourage scrap collection and to reduce the share of secondary supply.

The first target of the scrap producers (represented by the National Association of Recycling Industries, NARI) was the primary depletion allowance, for which scrap dealers, being in the manufacturing class of establishment, failed to

Table 23. FORECAST OF DIRECT-REDUCED IRON PRODUCTION (1982)

Countries and Regions	Forecast 1982 World Production	For Consumption U.S. Scrap Export Markets	For Export to U.S. Scrap Export Markets	Exported Directly to the U.S.
European Community	409	409	-	-
Japan	168	168	-	-
Other Asia	1,602	1,079	-	-
Other Western Europe	262	262	-	-
United Kingdom	838	838	-	-
Latin America	7,864	7,707	-	157
Canada	1,424	1,319	-	105
Eastern Europe	-	-	-	-
South Africa	1,173	1,173	-	-
Oceania	126	126	-	-
Middle East	5,948	628	1,832	-
Other Africa	785	-	-	-
United States	1,168	-	-	-
Totals	21,767	13,709	1,832	262

Source: W. Hogan and F. Koeble, Purchased Ferrous Scrap: U.S. Supply-Demand Outlook (AINSI, June, 1977, p. 91)

qualify. NARI, in several Congressional hearings, also succeeded in establishing that railway tariffs had been set higher for scrap copper than primary copper over the same distance, and that increases in rates bear more heavily on scrap dealers. Their submission to the Subcommittee on Fiscal Policy (1971) on railway freight rates is reproduced in table 24.⁹¹

The case against the railways was not clear-cut, because, as the carriers pointed out, scrap is more costly to haul than many other commodities since it is bulky, less easily handled, and tends to be transported in smaller lots.

In order to counteract the alleged discrimination against them, the scrap industry is lobbying hard not only for equality with primary producers, but for significant subsidies to scrap dealers and secondary processors. Their specific recommendation in testifying before the Senate Finance Committee was for a 10 percent tax credit for scrap equipment purchases.⁹² So far there has not been a major breakthrough in that direction, however. The National Resource Recovery Act of 1970 merely instructed the Environmental Protection Agency to pay particular attention to the problems, and no major new subsidies have so far been achieved.

Table 24. RAILWAY FREIGHT DIFFERENTIALS: ORES VS. SCRAP
(cents per 100 lb.)

Rate Change	Ores	Scrap	Difference
Rate Prior to Exparte 223	51.7	65.1	13.3
Exparte 223 (1960)	52.2	65.5	13.3
Exparte 256 (1967)	53.3	67.5	14.2
Exparte 259 (1968)	55.0	71.0	15.0
Exparte 262 (1969)	59.0	75.0	16.0
Exparte 265 (1970)	62.8	79.0	16.2
Exparte 267 (1971)	70.3	88.0	17.7

Source: Statement of M.J. Mighdoll, Executive V.P., NARI, to the Subcommittee on Fiscal Policy of the Joint Economic Committee of Congress, November 9, 1971, (U.S. GPO, 1972).

If such a scrap industry subsidy program were passed, then, on the strength of our estimates of elasticities, we can give some idea of its effects. Suppose there is a 10 percent overall subsidy on scrap processing. In general, a percentage subsidy will decrease the price that consumers must pay for the product, although it will increase the price received by the vendor. The extent to which the scrap consumer's price will fall depends on the elasticity of scrap supply (as well as demand). The price reduction will be greater, the larger the suppliers' responsiveness to price. Previous researchers have predicted that scrap subsidies would be effective in promoting scrap use, based on their high elasticity estimates for old scrap supply. However, we have seen how in recent years these estimates have been revised downward as the result of taking the depletion of scrap stocks into account.

First, excluding our own estimate, the average post-1976 old scrap supply elasticity estimate is about unity, giving an overall scrap supply elasticity of .144. When combined with an average scrap demand elasticity of -.62, this means a 10 percent scrap subsidy would be expected to lower scrap prices by only about 2 percent and increase scrap supply by only 1.2 percent. Our estimates are even lower, giving a predicted price effect of only .4 percent and scrap supply increase of .1 percent. Based on the existing commercial scrap collection and processing system, it is thus unlikely that simple subsidies will be effective in promoting the substitution of scrap for primary metal. Such a goal would require significant efforts to increase the supply of processable scrap through, for example, improvements in municipal refuse collection systems.

7. CONCLUSIONS

Introduction

This study of U.S. scrap markets in copper and ferrous metal has focused on the degree of substitution of scrap for primary metal; specifically, the trade-off of costs and benefits to Canada involved in the encouragement of scrap metal processing on both sides of the border. The benefits of the substitution of scrap for primary metal are lower levels of energy use and of sulphur dioxide emissions; the costs for Canada are losses of employment in primary export industries.

The study has proceeded by outlining the structure of the relationships of Canadian primary metal to U.S. scrap markets in chapters 1 and 2, and then building econometric models for copper and ferrous metal in chapters 5 and 6 in an attempt to qualify these relationships in more detail. In the remainder of this chapter, the substantive findings of the study are given under five general headings for each of copper and ferrous metal:

- i the importance of U.S. scrap markets to Canadian primary exports;
- ii the structures of these scrap markets and changes in these structures;
- iii factors influencing scrap demand and supply;
- iv the interactions between primary and secondary markets, including the effects of scrap prices on Canadian primary exports;
- v implications of energy price changes, primary metal grade decline, environmental controls, and other factors for primary and secondary metal markets.

Primary and Secondary Copper Markets

Canadian Exports and U.S. Scrap

Of \$6.3 billion in nonferrous metal production in 1980, \$1.8 billion was in copper, 60 percent of which was exported. Overall, nearly 30 percent of all exports are minerals.

Of total copper exports, 60 percent are exported in the form of concentrates, mainly to Japan. Concentrate exports are not greatly affected by the scrap market. Of refined metal production, 48 percent was exported in 1979, and 37 percent of these exports or \$321 million went to the USA. The U.S. scrap market competes directly with this \$321 million in sales.

However, the scrap market has more than just a direct influence on Canadian copper production. It also affects copper prices, especially the London Metal Exchange price; Canada's European sales (representing most of the rest of our copper exports) are priced at the prevailing LME price.

Scrap represents over 50 percent of total consumption in copper, as well as in lead and zinc. U.S. scrap supply represents about eight times Canadian refined production.

The Structure of the Scrap Copper Market

Secondary copper supply is divided into three general components: home, new, and old scrap, of which home scrap is about 30 percent, new about 45 percent, and old scrap about 25 percent of the total. The home scrap component appears to be a smaller proportion than is the case with ferrous scrap.

In contrast to ferrous scrap, new copper scrap supply, derived from waste in copper fabricating, appears to be rising in proportion to copper consumption, from 30 percent in 1960 to about 45 percent in 1979. This represents an upward trend in total scrap generation.

Old copper scrap supply taps the stock of discarded copper products. The dependence of old scrap flows on the stocks of scrap can impart instability to copper markets.

New scrap is purchased mainly by brass mills and competes directly with refined copper. It tends to be higher-grade material and close to primary grade in quality. Old scrap, in contrast, generally must undergo smelting or refining by either primary refiners or secondary smelters before re-entering the copper market.

The copper brass mill industry is still workably competitive, although it has become more concentrated in recent years. Secondary smelting is less competitive, and the primary copper industry is oligopolistic in structure. Primary refiners have to some extent integrated forward by purchasing both brass and wire mills, thus limiting the competition of scrap for primary copper.

Scrap and Primary Demand and Supply Response

Changes in copper prices are often dramatic, because of the relative lack of response of demand and of supply in both primary and secondary markets. Estimates of overall U.S. refined copper demand elasticity, including an

estimate made for this study, are low: a value of about $-.3$ for a single year, meaning that a 10 percent rise in prices reduces demand by only 3 percent. Primary copper supply is also unresponsive to price both in Canada and the USA.

New scrap supply changes with copper consumption, but its supply is usually regarded as being unresponsive to copper scrap price changes. Unlike previous studies, however, we found a significant new scrap supply elasticity of $.36$. The increased responsiveness of new scrap to price in recent years may be the result of large scrap processors' gaining more control of scrap markets in the USA. These processors have the working capital to speculate by holding scrap off the market in periods of low prices.

Old scrap, because its supply depends on the stock of obsolete products, is more responsive to price changes in the short than in the long run. This may tend to cause instability in copper prices.

Old copper scrap probably benefited somewhat from the introduction of the shredder and magnetic separator for ferrous scrap, releasing nonferrous material that was formerly lost in the number 2 bundle. However, this technological change has now been completed.

The substitution of aluminum for copper in many applications has presumably affected the supply of obsolete copper scrap, although no dramatic evidence has so far appeared. The absence of evidence may be because (a) the life of many durable goods is very long (15-25 years) and the drop in scrap supply will occur in the future or, (b) the decline in scrap has been counteracted either by shifts in the mix of copper products or by reduced lifetimes of durable goods because of declining quality. At present there seem to be no major trends in old scrap supply.

Interactions between Primary and Secondary Copper Markets

The London Metal Exchange copper price and the number 2 scrap price are both related to U.S. and European durable goods production, increasing roughly in proportion.

The U.S. producer price of copper, regulating Canadian sales in the U.S. market, has responded slowly to changes in the LME price in the 1958-79 sample period, on average taking about two years to adjust. There is much more rapid adjustment in evidence in recent years, as the result of less rigidity in the copper market.

Canadian producers to some extent have switched to copper sales between European and U.S. markets in response to producer-LME price differences. Their overall response to price change is very small, however, implying that scrap has not significantly affected export volume, only its price.

On the basis of our estimated scrap supply elasticities, we calculated the effects of scrap supply response on the LME copper price. In the past, a 10 percent increase in both U.S. and European durable manufacturing activity has been associated with, on average, a 12.3 percent rise in the LME price. With both new and old scrap fixed in supply, we calculated that this would be 15.9 percent, because the increased supply of copper material dampens copper prices. With only old scrap inelastic, this price change would be 12.9 percent, so most supply response comes from new scrap.

Exogenous Changes in Copper Markets

Although primary copper production is energy intensive and secondary copper considerably less so, energy price changes have not greatly affected either copper prices or the scrap market share. Copper prices do not change with energy prices because, although costs rise, demand falls.

Energy prices are potentially more important in conjunction with declines in primary copper yields, which fell from .89 percent in 1949 to .49 percent in 1979. On average, a 1 percent fall in copper yields (from .50 percent to .495 percent, say) raises copper prices 1.7 percent, other things being equal. As processing of lower-grade ore is more energy intensive, energy price changes also become more important as grade falls.

Emission controls seem to have more important long-term than short-term effects on the copper market. It has been estimated elsewhere that proposed U.S. controls on smelter emissions would raise primary production costs about 2.5 cents per pound in the short run, but would have their major effects in constraining primary capacity by 25 to 33 percent. As secondary processors would be much less affected, they were projected to increase their output by 17 to 23 percent in the U.S. market, the remainder coming from imports (probably non-Canadian).

Scrap in Ferrous Markets

Canadian Iron Ore and the U.S. Scrap Market

Canadian mine shipments of iron ore have averaged from 50 to 60 million tonnes in recent years, with a value in 1980 of \$1.7 billion. 81 percent was exported in that year.

Of total Canadian ore exports, half go to the U.S. market (about 23 million tonnes), with the remainder divided between Europe and Japan.

Exports to the USA are now in the form of pellets, a superior product, that compete in that market with U.S. ore and scrap, as well as with imports from Venezuela and Brazil. The export of concentrates from British Columbia to Japan can be regarded as part of a separate market.

Ferrous scrap production in the USA of 89.7 million tonnes in 1979 represented more than six times the volume of Canadian exports to that market, and nearly 75 percent of the total 127.5 million tonnes of iron ore consumed. Its importance was greater than this, however, because scrap competes directly with the 87.1 million tonnes of pig iron produced from iron ore (with 48 percent of the total steel furnace metallic input) and thus one tonne of scrap replaces nearly 1.5 tonnes of iron ore. Scrap supply in the USA is such that scrap is exported in significant amounts to Japan and Europe.

Ferrous Scrap Market Structure

Of the three major ferrous scrap types, home scrap, representing about 50 percent of the total, is more important than in the case of copper. Its supply has also been quite variable. In relation to total ingot production, home scrap generation increased from about 25 percent to 32 percent from 1950 to 1970 as a result of declining efficiency in steel finishing. This trend has been reversed since 1970 with the introduction of continuous casting as a steel finishing process. In 1979 home scrap was 28 percent of raw steel. Over the whole of the period 1960 to 1979 there was a slight falling trend of -0.76 percent per year.

New scrap averages 16.6 percent of total finished steel and represents 60 percent of total purchased scrap, up from 40-45 percent in 1960. The remaining supply is old scrap, representing 20 percent of total generation. Old scrap generation is projected to fall because less steel is being used in new automobiles; steel content will fall from 2530 pounds in a typical 1969 auto to a projected 1600 pounds in 1985. This will, however, take about 10 years to be reflected in scrap generation.

Unlike copper scrap, ferrous scrap competes directly with pig iron in steel furnaces without intermediate smelting or refining. The share of scrap is different in different furnaces, for technical reasons, and changes with changes in furnace shares. The major change in steelmaking since 1950 has been the replacement of the open hearth (OH) furnace, which used relatively more scrap, by the basic oxygen furnace (BOF), where scrap is limited to about 30 percent. Since 1960, the OH furnace share has declined 12.6 percent per year, on average, while the BOF share increased at 17.9 percent per year. The overall scrap share has not declined because of the simultaneous growth of electric furnaces using nearly all scrap.

Ferrous Scrap Supply and Demand Response

A surprising new finding of the study is the apparent negative relationship of home scrap generation with scrap prices, (after steel output and the exogenous trend are accounted for), meaning that high scrap prices induce steelmakers to be more efficient in steel fabricating because of higher steel production costs. We calculated home scrap to have an elasticity of 1.12 with total steel, a -.76 percent falling trend, and a -.11 price elasticity.

New scrap generation is independent of scrap prices but has an elasticity with respect to total steel output of 1.16.

Previous studies have regarded old scrap generation as very responsive to scrap prices. Recently, these estimates have come down. Our estimated old scrap elasticity was .59 within a single year and .09 after several years. In combination with the negative relationship of home scrap to output, this means a low overall scrap supply response to price of .1 or less.

The scrap/pig-iron ratio within a given steel furnace was found to be insensitive to scrap prices. However, the shares of the BOF and electric furnaces in total steel output were found to respond both to scrap prices and to changes in total steel output. The price elasticity of overall scrap demand was estimated as -.32 and the elasticity with respect to total steel output was .669. Pig iron output, in contrast, expands more than proportionally with the total steel, with an elasticity of 1.2. There is evidence of significant scale economies in U.S. blast furnace operations.

Canadian iron ore exports were found to vary with pig iron output in U.S. blast furnaces, with an elasticity of 1.42 with pig iron and, indirectly, 1.73 with total steel output.

Scrap and Ore Prices and Canadian Ore Exports

The number 2 scrap price was found to vary positively with steel output with an elasticity of 1.45, while the merchant pig iron price declined approximately in proportion. The Lake Erie price of pellets was not related to steel output, probably because this price is not determined as the result of a market transaction, as are scrap prices, but is mainly a transfer price for intra-firm sales. An index of natural ore prices in the USA, perhaps more responsive to market forces, was found to be significantly but fairly weakly related to total pig iron output.

Canadian ore demand, while responding strongly to U.S. steel output increases, was also affected by scrap price changes, a 1 percent increase in the number 2 scrap price increasing ore demand by .12 percent through substitution of pig iron for scrap. With 1979 exports to the USA of about 770 million, this .12 percent change increases Canadian ore export value by .9 million per 1 percent change in the scrap price.

Potential Developments Affecting the Scrap/Pig-Iron Balance

A technical development that may change the scrap/ore relationship involves the renewed popularity of an old process for the direct reduction of iron ore into a form that can be used directly in steel furnaces, bypassing the blast furnace. It is a process in which the cost of utilizing ore is reduced, and will therefore result in the substitution of ore for scrap in the future. Direct reduction capacity has been installed in Canada as well as in many ore-rich developing countries. However, direct reduction facilities in other countries may indirectly reduce the benefits to Canadian producers of iron ore, since their installation will lead to a reduction in scrap exports from the USA. Hogan and Koeble have forecast an increase of about 8 percent in U.S. domestic scrap supply from 1977 to 1982 as the result of reduced export markets, and the resulting fall in scrap prices may make Canadian ore less attractive in U.S. markets.

There was strong political pressure for legislation in favour of the use of scrap in the last decade. In the past, researchers have suggested that subsidies favouring the scrap industry would be very effective in promoting substitution of scrap for pig iron and iron ore. In contrast, our research, as well as other recent estimates, indicates that with the present commercial scrap processing system there is little potential for inducing a shift in that direction through subsidies to the scrap industry. The pool of unused scrap is growing in

North America, and unfortunately it will continue to grow until ways are found to make municipal garbage and other low-grade scrap sources commercially exploitable.

Limitations of the Study and Suggestions for Future Research

The main limitation of the study is its concentration on the metal markets in North America. Although it explicitly recognizes that both the copper and steel markets are world-wide, building realistic models of the world copper, steel, ore and scrap markets was beyond the scope of the study. Thus, while the scrap markets in the USA are certainly large enough to affect world metal prices, there are significant amounts of generated scrap in other heavily industrialized countries (in Europe for example), the influence of which should be taken into account. Similarly, while U.S. demand for Canadian primary metal is important, the European demand for refined copper or the Japanese demand for copper concentrates are of equal significance to Canada. Some research to build a world copper market model has been done by the larger contract research institutes such as the Charles River Associates of Cambridge, Massachusetts, but even their model is highly aggregative. Larger and more flexible models are currently being built by these institutes.

The study has also been constrained by a shortage of data concerning the structure of the scrap, ingot maker, and brass mill industries. Ingot makers and brass mills are not separated in the statistics of the U.S. Bureau of Mines, and data on concentration in these separate industries and the extent of the intercorporate relationships with either primary mining or downstream fabricating companies are not consistently documented. Data on the Canadian secondary metals industry are even more scarce. These data are vitally necessary if more is to be learned about the important but relatively little-researched secondary metals industry.

APPENDICES

APPENDIX I COPPER SCRAP MARKET INTERACTIONS

The conclusions of the section on copper are derived from the following model for the refined, new, and old scrap markets:

$$Df(Pf, Ps_1, DUR) = Sf(Pf, Ps_2)$$

$$Ds_1(Pf, Ps_1, DUR) = Ss1(Sf(Pf, Ps_2))$$

$$Ds_2(Pf, Ps_2) = Ss2(Ps_2, A).$$

Differentiating totally in logarithmic form, the percentage changes in Pf , Ps , and Ps_2 (Pf, Ps_1, Ps_2) are related in matrix form with corresponding changes in DUR and A by the elasticities of demand and supply:

$$\begin{bmatrix} Eff - Nff & Efs & -Nfs^2 \\ Esf^1 - Nsy^1 Nff & Ess^1 & -Nsy^1 Nfs^2 \\ Esf^2 & 0 & Ess^2 - Nss^2 \end{bmatrix} \begin{bmatrix} \hat{P}f \\ \hat{P}s^1 \\ \hat{P}s^2 \end{bmatrix} = \begin{bmatrix} -Efy \hat{D}ur \\ -Esy \hat{D}ur \\ Nsa^2 \hat{A} \end{bmatrix}$$

Eff and Nff are refined copper demand and supply elasticities, i.e., $dDf/dPf(Pf/Df)$; Efs is the effect of Ps^1 on Df ; Efy the income elasticity (DUR on $\hat{D}f$), and similar notation applies to new scrap (Ess^1 is the 'own price demand' elasticity) and to old scrap (Ess^2). The model is then solved by Cramer's rule to find Pf , Ps^1 , and Ps^2 as functions of DUR and A . For example, it can be shown that $\hat{P}s^1/\hat{D}ur \leq 0$, while the obsolete scrap price will always rise in response to an overall demand increase ($\hat{P}s^2/\hat{D}ur > 0$). This follows, of course, because new scrap supply as well as demand shifts rightward as DUR increases.

Mathematical Conditions of Steel Industry Cost Minimization

The cost function:

$$C = iK + WL + Ps_1Ds_1 + Ps_2Ds_2 + Pe(Ei + Ef) + Co(Do, Pe)$$

is assumed to be minimized subject to:

$$Sf = Sf(Kf, Lf, Ef, Si, Ds_1, Ds_2)$$

and

$$S_i = S_i(K_i, L_i, E_i, D_o),$$

Where L is labour, D_{s1} and D_{s2} the scrap inputs, S_i and S_f the supply of pig iron and steel, respectively, E energy use, and D_o the demand for iron ore. We form the Lagrangian function,

$$C' = iK + wL + P_{s1}D_{s1} + P_{s2}D_{s2} + P_e(E_i + E_f) - C_o(D_o, P_e) + \gamma (S_f - S_f(K_f, L_f, E_f, S_i(K_i, L_i, E_i, D_o), D_{s1}, D_{s2})).$$

Minimizing this gives the conditions:

$$\gamma (dS_f/dL_f) = w \quad \gamma (dS_f/dS_i)(dS_i/dD_o) = MCo$$

$$\gamma (dS_f/dD_i) = P_{s1} \quad \gamma (dS_f/dE_f) = P_e$$

$$\gamma (dS_f/dD_{s2}) = P_{s2} \quad \gamma (dS_f/dS_i)(dS_i/dE_i) = P_e$$

where γ is the shadow price of steel output (the administered price of steel).

Suppose the production functions are assumed of the Cobb-Douglas form as regards scrap, labour, and pig iron in steel and labour and ore in pig iron, but with zero substitution elasticity with respect to energy, i.e.:

$$\log S_f = \min \log E_f, (b_1 \log K_f + b_2 \log L_f + b_3 \log S_i + b_4 \log D_{s1} + b_5 \log D_{s2})$$

$$\log S_i = \min \log E_i, (a_1 \log K_i + a_2 \log L_i + a_3 \log D_o)$$

The resulting demand functions unconstrained by energy use are:

$$L = (a_1 b_3 + b_2) \gamma S_f / w \quad D_o = b_3 a_3 \gamma S_f / MCo(D_o, P_e)$$

$$D_{s1} = b_4 \gamma S_f / P_{s1} \quad D_{s2} = b_5 \gamma S_f / P_{s2}$$

Thus the demands for the inputs are proportional to γ and S_f (the price and volume of finished steel) and inversely related to the prices of the inputs (w , MCo , P_{s1} , or P_{s2}).

APPENDIX II ESTIMATED COPPER MARKET MODEL

The estimated copper market model consists of equations estimating refined copper demand as well as the market supply of U.S. and Canadian primary refined copper, secondary refined supply, and new and old scrap in the USA. These relationships are estimated taking account of the interrelationships of demand, supply, and price. The prices of refined and scrap copper are then estimated as functions of exogenous variables such as an index of general economic activity, the grade of ore mineral in the USA, and other variables representing export controls etc. The period of estimation was from 1956 to 1979.

The exogenous variables in the model are:

Dur - the Federal Reserve Durable Manufacturing index (1967 = 100)

Strike - dummy variable for primary copper strikes

D72 - dummy variable for 1972 international supply disruptions.

Pe - U.S. price of electricity. From Handbook of Labor Statistics (U.S. Dept. of Labor, Dec. 1980)

w - Average weekly wages in secondary copper refining. From Employment and Earnings in the United States, U.S. Dept. of Labor.

g - Average yield of primary metal in USA. From Minerals Yearbook (various issue)

Xc - a dummy variable for scrap export controls, 1964-69

NOTE: In the equations below the first number in brackets under a variable is the student t statistic. The second is the elasticity with respect to the variable, evaluated at means.

1. Refined Copper Demand

$$\begin{aligned} D_f = & 698.9 + 7.35 \text{ Dur} - 9.31 \text{ Pf}(-1) \\ & (3.6)(14.9) \quad (-2.5) \\ & (.88) \quad (-2.5) \end{aligned}$$

Method = OLS $\bar{R}^2 = .89$ D.W. = 1.99

Autoregressive $p_1 = .26$ $p_2 = -.28$

2. New Scrap Supply

$$S_n = -71.557 + 6.96 P_{s2} + .268 D_f$$

(-1.5)	(3.5)	(5.0)
	(.355)	(.75)

method = 2sls $\bar{R}^2 = .96$ D.W. = 2.02

$$S_n = -158.4 + .4405 D_f$$

(-2.6)	(13.8)
	(1.24)

$\bar{R}^2 = .89$ D.W. = 1.63

3. Secondary Refiners Scrap Demand

$$D_{s2} = -119.5 + 162.1 (P_f/P_{s2}) + 475.5 (P_f/P_{elec}) + .13 D_{s2}(t-1)$$

(-1.1)	(2.0)	(4.9)	(.9)
	(1.30)	(.60)	

$\bar{R}^2 = .57$ D.W. = 1.9 method = 2sls

4. Old Scrap Supply

$$S_{s2} = 368.01 + 4.577 P_{s'2} + 92.48 \text{ Trend} + .025 D_f - .303 S_{s2}$$

(2.4)	(5.6)	(1.6)	(1.4)	(-2.2)
	(.33)	(3.7)	(1.5)	(-5.3)

method = 2sls $\bar{R}^2 = .81$ D.W. = 1.4

5. Secondary Refined Supply

$$S_s = 233.18 + 4.49 P_f + 1.53 P_e - 2.22 w - 3.29 P_{s2}$$

(9.1)	(2.3)	(2.4)	(-3.6)	(-.9)
	(.74)	(.82)	(-.94)	(-.35)

method = 2sls $\bar{R}^2 = .82$ D.W. = 1.93

6. U.S. Primary Supply

$$S_p = 1610.5 + 7.80 P_p - 7.17 P_p(t-1) - 170.1 D72$$

(17.7)	(2.5)	(-1.9)	(-1.2)
	(.23)	(-.20)	

$\bar{R}^2 = .65$ D.W. = 1.47

7. Canadian Primary Supply

$$\begin{aligned}
 Cx/Df &= .085 + .001 Df - .014 Pf/Pp - .001 Pe \\
 &\quad (5.0) \quad (1.4) \quad (1.3) \quad (-2.0) \\
 &\quad \quad (.61) \quad (.30) \quad (-.36) \\
 &+ .016 UStrike - .001 CStrike - .001 Sp(-1) \\
 &\quad (2.9) \quad (-2.8) \quad (-1.7) \\
 &\quad \quad \quad (-.62) \\
 \bar{R}^2 &= .57 \quad D.W. = 1.86
 \end{aligned}$$

8. The LME (market) price of copper

$$\begin{aligned}
 Pf &= 24.76 + .283 Dur - 57.19 g - 25.83 D72 \\
 &\quad (3.2) \quad (-1.6) \quad (-2.0) \\
 &\quad (1.23) \quad (-.6) \\
 \bar{R}^2 &= .76 \quad D.W. = 1.8
 \end{aligned}$$

9. The Refinery Buying Price of Number 2 Scrap

$$\begin{aligned}
 Ps_2 &= 7.48 + .686 Pf + 11.69 D72 - .0144 Ss_2(t-1) \\
 &\quad (3.2)(12.7) \quad (3.4) \quad (-2.2) \\
 &\quad (1.05) \quad (.01) \quad (-.27) \\
 \text{method} &= 2sls \quad \bar{R}^2 = .95 \quad D.W. = 1.80
 \end{aligned}$$

10. The Producer Price of Copper

$$\begin{aligned}
 Pp - Pp(-1) &= .518 (Pf - Pp(-1)) - 9.1399 Xc \\
 &\quad (6.7) \quad (-3.4) \\
 \bar{R}^2 &= .94 \quad D.W. = 1.8 \quad \text{method} = 2sls
 \end{aligned}$$

11. The Secondary Refiners' Margin

$$\begin{aligned}
 (Pf - Ps_2)/Pf &= .139 + .001 Pf(-1) + .119 D72 + .055 Xc \\
 &\quad (5.3) \quad (1.9) \quad (2.9) \quad (2.6) \\
 \bar{R}^2 &= .54 \quad D.W. = 2.06 \quad \text{method: autocorrelation correction}
 \end{aligned}$$

12. The Scrap Dealers' Margin

$$\begin{aligned}
 (Ps_2 - Ps'_2)/Ps_2 &= .077 + .002 Ps_2(-1) - .479 D72 - .029 Xc \\
 &\quad (2.6) \quad (2.8) \quad (-16.6) \quad (-1.3) \\
 \bar{R}^2 &= .926 \quad D.W. = 1.81 \quad \text{method} = \text{autocorrelation correction} \\
 Ps'_2 &\text{ is the dealer buying-price of number 2 copper scrap.}
 \end{aligned}$$

13. The Price of Copper on Comex

$$P_{cmx} = .592 + .975 P_f$$

(.5) (52.8)
(1.0)

$$\bar{R}^2 = .993 \quad D.W. = 2.3 \quad \text{method} = \text{autocorrelation correction}$$

Calculation of the Price Effects of Scrap

The effect of equal changes in Dur and $WDur$ on P_f in the short run is calculated as follows, where a circumflex denotes percentage change:

$$P_f = -E_{fy} (D\hat{U}_r + (Dw/Du) W\hat{D}\hat{U}_r) / Eff + (am N_m - s_1 N_{ss1} - s N_s) / (1 - s_1 N_{sy1})$$

where E_{fy} = s.r. income elasticity of demand (.58)

Dw/Du = proportion of foreign to U.S. consumption (2.67 average)

Eff = price elasticity of demand (-.31 in s.r.)

m = import share (.149 average)

N_m = elasticity of U.S. import demand (calculated as -11.7)

s_1 = share of new scrap to total copper (.221 average)

s = secondary producers' share (.157)

N_{ss1} = price elasticity of new scrap (.35)

N_{sy1} = activity elasticity of new scrap (.75)

N_s = overall secondary processors' supply elasticity (about .5)

APPENDIX III ESTIMATED FERROUS SCRAP MODEL EQUATIONS

The ferrous scrap model consists of equations for within and between furnace substitution of scrap for pig iron in the U.S. steel industry, as well as scrap supply equations and equations for the demand for pig iron and Canadian iron ore. All equations except for Ss_2 are in double logarithmic form (the variables are in logarithms), making the equation coefficients the elasticities with respect to the associated variable. In brackets under the coefficients are t coefficients.

List of Variables

- Dso, Dsb and Dse - demand for scrap in open hearth, basic oxygen and electric furnaces, respectively.
- Sfo, Sfb, Sfe - steel production in open hearth, basic oxygen and electrical furnaces.
- Sf - total U.S. steel production
- Coke - total coke production
- Di - total pig iron demand
- Doc - Canadian iron ore demand
- Sh - home scrap generation
- Sn - new scrap generation
- Ss_2 - old scrap supply
- A(t) - estimated stock of obsolete scrap held by dealers
- Pf - a BLS index of basic steel prices
- Po₁ - an index of lake Erie ore prices (pellets and natural ores)
- Po₂ - the lake Erie pellet price
- Ps₁ - Composite No. 1 H.M. scrap price
- Pi - average of mid-continent cold merchant pig iron prices
- Pcoal- index of coal prices
- Pe - index of electricity prices
- D73 - dummy variable (equals 1 in 1973, 0 otherwise)

1. Within Furnace Demand

$$Dso/Sfo = -.6024 - .12173 Sfo + .035 D73 - .0256 Ps_1/Pf$$

$$\begin{array}{cccc} (-4.7) & (-5.4) & (1.6) & (-.7) \end{array}$$

$$\bar{R}^2 = .856 \quad D.W. = 2.5 \quad \text{method} = 2sls$$

$$Dsb/Sfb = -.908 + .016 Sfb - .041 D73 + .090 Ps_1/Pf + .030 \log(Sfb/Sf)$$

$$\begin{array}{ccccc} (-15.9) & (3.2) & (-1.9) & (1.7) & (4.4) \end{array}$$

$$\bar{R}^2 = .473 \quad D.W. = 1.8 \quad \text{method} = 2sls$$

$$\begin{aligned} \text{Dse/Sfe} &= .880 - .085 \text{ Sfe} + .032 \text{ D73} - .037 \text{ Ps}_1/\text{Pf} + .425 \text{ lag}(\text{Dse/Sfe}) \\ &\quad (1.3) \quad (-1.3) \quad (.3) \quad (-.2) \quad (2.1) \\ \bar{R}^2 &= .458 \quad \text{D.W.} = 2.01 \quad \text{method} = 2\text{sls} \end{aligned}$$

2. Between Furnace Substitution

$$\begin{aligned} \text{Sfo/Sf} &= 1.04 + .731 \text{ Sf} - .073 \text{ Ps}_1/\text{Pf} - .041 \text{ Trend} - .005 \text{ Pe/Pf} \\ &\quad (17.7) \quad (4.0) \quad (-2.9) \quad (-12.0) \quad (-.16) \\ \bar{R}^2 &= .909 \quad \text{method} = 2\text{sls, autocorrelation correction} \quad \text{D.W.} = 2.18 \end{aligned}$$

$$\begin{aligned} \text{Sfb/Sf} &= -.484 + .284 \text{ Sf} + .326 \text{ lag}(\text{Ps}_1/\text{Pf}) + .037 \text{ Trend} + 2.36 \text{ Pe/Pf} \\ &\quad (-3.5) \quad (-4.0) \quad (2.1) \quad (20.5) \quad (2.7) \\ \bar{R}^2 &= .954 \quad \text{method} = \text{autocorrelation correction} \quad \text{D.W.} = 2.04 \end{aligned}$$

$$\begin{aligned} \text{Sfe/Sf} &= .080 - .56 \text{ Sf} + .015 \text{ lag}(\text{Ps}_1/\text{Pf}) + .008 \text{ Trend} - .031 (\text{Pe/Pf}) \\ &\quad (3.8) \quad (-6.1) \quad (.76) \quad (21.1) \quad (-2.1) \\ \bar{R}^2 &= .969 \quad \text{method} = \text{autocorrelation correction} \quad \text{D.W.} = 2.20 \end{aligned}$$

Total scrap demand elasticity was calculated as -.20, a combination of the coefficients on the price variables in the regressions above. Foundry use was treated as a residual.

3. Pig Iron Demand

$$\begin{aligned} \text{Di} &= -3.32 + 1.21 \text{ Sf} + .085 \text{ lag}(\text{Ps}_1/\text{Pf}) + .113 \text{ lag}(\text{Pi/Pf}) + .318 \text{ Pe/Pf} \\ &\quad (-3.7) \quad (19.3) \quad (2.4) \quad (.96) \quad (1.3) \\ \bar{R}^2 &= .982 \quad \text{D.W.} = 1.8 \quad \text{method} = \text{ols} \end{aligned}$$

4. Canadian Ore Demand

$$\begin{aligned} \text{Doc} &= -6.836 + 1.424 \text{ Di} - .314 \text{ Po}_2/\text{Pf} - .339 \text{ CStrike} \\ &\quad (-2.5) \quad (5.2) \quad (-.94) \quad (-4.9) \\ \bar{R}^2 &= .78 \quad \text{D.W.} = 2.05 \quad \text{method} = 2\text{sls} \end{aligned}$$

5. Scrap Supply

$$\begin{aligned} \text{Sh} &= 12.67 + 1.125 \text{ Sf} - .008 \text{ Trend} - .116 \text{ Ps}_1/\text{Pf} \\ &\quad (5.8) \quad (18.9) \quad (-5.8) \quad (-3.7) \\ \bar{R}^2 &= .959 \quad \text{D.W.} = 2.09 \quad \text{method} = 2\text{sls} \end{aligned}$$

$$S_n = -3.113 + 1.156 S_f \\ (-1.8) \quad (7.9)$$

$$\bar{R}^2 = .995 \quad D.W. = 1.74$$

$$Ss_2 = 2.38 + .460 A(t) + 2.862 \log(Ps_1/Pf) - 2.46 \log(Ps_1/Pf)_{-1} - .260 Shred \\ (3.9) \quad (3.4) \quad (-2.0) \quad (-1.9)$$

$$\bar{R}^2 = .55 \quad D.W. = 1.7 \quad \text{method} = 2sls$$

6. Scrap, Iron, and Ore Prices

$$Ps_1/Pf = -12.30 + 1.45 S_f + 1.65 Pi/Pf + .326 D73 - .239 Pcoal/Pf - 3.95 Pe/Pf \\ (-2.8) \quad (3.4) \quad (3.7) \quad (3.8) \quad (-2.7) \quad (-1.8)$$

$$\bar{R}^2 = .783 \quad D.W. = 2.16 \quad \text{method} = 2sls$$

$$Pi/Pf = 5.00 + .155 Po/Pf + .149 Pcoal/Pf + .686 Coke + .129 Ps_1/Pf - 1.07 S_f \\ (5.4) \quad (1.3) \quad (6.8) \quad (4.8) \quad (3.2) \quad (-11.3)$$

$$\bar{R}^2 = .93 \quad D.W. = 1.8 \quad \text{method} = 2sls$$

$$Po_1/Pf = 1.77 + .98 \log(Po_1/Pf) + .128 Ps_1/Pf - .300 Coke + .172 Di \\ (2.4)(10.8) \quad (3.6) \quad (-2.9) \quad (2.1)$$

$$\bar{R}^2 = .938 \quad D.W. = 2.39 \quad \text{method} = 2sls$$

$$Po_2 = -.440 + .930 \log(Po_2) + .141(Ps_1/Pf) - .086 (Ps_1/Pf)*D74 \\ (7.4) \quad (1.9) \quad (-1.0)$$

$$\bar{R}^2 = .74 \quad D.W. = 2.27 \quad \text{method} = 2sls$$

NOTES

NOTES

1. Statistics from Statistics Canada, Canada's Mineral Production CAI-5c26-202, Ottawa, 1979 and 1980.
2. The year 1979 is employed for comparison not because it is representative but simply because it is the last year for which complete statistics were available at the time of writing. 1979 was in retrospect a relative boom year in the industry. Although distortion may occur because of the Inco and Gaspé strikes in Canada, use of this year misses the 1980 U.S. copper strikes and the unprecedented 1981-82 slump.
3. EMR, Canadian Minerals Yearbook, Ottawa, 1979, p.7.
4. Of 318.3 thousand metric tonnes of concentrate exported in 1979, representing 62 percent of total exports, 233.5 thousand went to Japan (73.4%) and 29.3 thousand (9.2%) to EEC countries. Virtually no concentrates are exported to the USA.
5. For an excellent detailed study of Canadian nonferrous metal markets, see E. Urquhart, The Canadian Nonferrous Metals Industry: An Industrial Organization Study, Kingston, Centre for Resource Studies, 1978.
6. The exact proportions in 1979, according to the U.S. Bureau of Mines Minerals Yearbook 1979-80, were 50.3 percent for aluminum, 49.1 percent for copper, 45.5 percent for lead, 37.9 percent for nickel, and 26.8 percent for zinc.
7. Statistics Canada, Canada's Mineral Production, SC 26-202, Ottawa, 1980.
8. C.J. Cajka, 'Iron Ore' in EMR, Canadian Minerals Yearbook, 1979.
9. Bringing net exports to 71.4 percent of production.
10. U.S. Bureau of Mines, Minerals Yearbooks, various years.
11. These statistics are derived from Statistics Canada, General Review of the Mineral Industries: Mines, Quarries and Oil Wells, SC 26-201, and are quoted in C.H. Pye, Profitability in the Canadian Mineral Industry, Kingston, Centre for Resource Studies, 1981, p.82, table 16.
12. Ibid, tables 17 and 18, pp. 83 and 84. This applies to Canada, but would be expected to be true for U.S. mines as well. In particular, factor productivity changes in iron ore from 1961 to 1975 compensated about equally for grade decline in Canada, although this was not true for other metals.
13. C.F. Chapman, 'Energy Conservation and Recycling of Copper and Aluminum,' Metals and Materials, 1974, pp. 311-319.
14. B.E. Felske and Associates, Sulphur Dioxide Regulation and the Canadian Nonferrous Metals Industry, Technical Report no. 3, Ottawa, Economic Council, January 1981, p. 25.

15. Major ferrous scrap dealers in Canada are International Iron and Metal (Intermetco), I. Waxman and Sons, United Steel and Metal, Mostel Metals, Frank Levy Metals, and Solway and Sons. The largest nonferrous scrap dealers include United Smelting and Refining (Usarco), Ingot Metals, Federated Genco, and Metals and Alloys, with the last two specializing in zinc and aluminum, respectively.
16. Statistics from Statistics Canada, Nonferrous Scrap Metal, 1978 (SC 41-229). Publication discontinued in that year. Canada has been a net importer of copper scrap for the last two years, according to an industry source.
17. There were actually 9,311,400 tonnes of scrap generated in 1978 and 9,326,800 tonnes consumed, with exports and imports approximately balanced at 936,600 and 952,000 tonnes respectively, according to the Statistics Canada publication, Scrap Iron and Steel, 1978 (SC 41-212), August 1980. Of the 9.3 million tonnes of generated scrap, about 48 percent was home scrap, generated within the steel plants that used it, and the remainder was purchased from scrap dealers.
18. There is also an important interregional element in the ferrous scrap trade. Because steel-using industries such as automobile manufacturing are still located largely in Ontario and Quebec, despite the westward industrial drift, there is a scrap surplus in central Canada relative to both east and west. The high transport costs associated with scrap movements make it more economic for the regional western and eastern steelmills (which tend to use electric furnaces employing mostly scrap) to import scrap from the USA, while central Canada exports it in approximately equal amounts, instead of trading directly. Given this structure, a fall in scrap prices would also cause an interregional income transfer from central Canada to both eastern and western regions.
19. Interview with Jack Rosen of Rosen Metals, Kitchener, Ontario.
20. C.G. Branner, Iron and Steel Scrap in California U.S. Bureau of Mines Information Circular 7973, 1962.
21. Interview with Robert Spritz, head of marketing for Pacific Steel of San Diego, one of the half dozen relatively small ferrous dealers in that area who sell to large brokers in Los Angeles.
22. A description of the largest scrap dealers can be found in Charles Lipset, Wall Street Scrap Giants, (New York: Atlas Publishing, 1969).
23. This information was obtained in a personal communication from R. McInnis of the Ferrous Division, Mineral Policy Sector, Energy, Mines and Resources.
24. The U.S. producers' properties in Chile were nationalized in 1969. The Union Minière mines in Zaire (then Republic of the Congo) were nationalized in 1967, and the Zambian government obtained control of RST properties in 1970.

25. D.L. McNicol, 'The Two-Price Systems in the Copper Industry', Bell Journal (Spring, 1975), describes the two-price system and the copper industry. A second useful source is Gluschke, Shaw, et al., Copper - The Next Fifteen Years, United Nations, 1979, chapter 1, pp 13 - 23.
26. INCO reportedly sells little copper in the U.S. market, according to McNicol (op cit.).
27. U.S. Bureau of Mines, Minerals Yearbook, 1978-79.
28. U.S. Bureau of Mines, Minerals Yearbook, vol. 1, 1978-79, table 4, p. 494. Converted to metric tonnes.
29. Ibid, table 7, p. 478. Original data from the American Iron and Steel Institute Annual Statistical Review.
30. The use of scrap by ferrous foundries using cupola furnaces is excluded from the table. In 1979 this sector utilized 12.9 percent of total scrap.
31. Data are from The American Iron and Steel Institute, Annual Statistical Report for 1978. Total value of production was derived from the U.S. Bureau of the Census, Annual Survey of Manufacturing (1976) for SIC 3312 (Blast Furnaces and Steel Mills, p. 161) and converted to 1978 dollars.
32. See W. Adams and J. Dirlam, 'Steel Imports and Vertical Oligopoly Power,' American Economic Review, vol. 54, no. 5, Sept. 1964, p. 626-655.
33. For example, R. Manke, 'The Determinants of Steel Prices in the U.S.: 1947-65', Journal of Industrial Economics, 16-17, 1967/68, pp. 147-161; and L.B. Krause, 'Import Discipline: The Case of the United States Steel Industry', Journal of Industrial Economics 11-13, 1962/63, pp. 33-46.
34. Data from the U.S. Bureau of Mines, Minerals Yearbooks.
35. A study by the U.S. Tariff Commission estimated that 80 percent of iron ore consumed in the U.S. is captive ore. Quoted in W.I. Greenwald, 'Supply Shifts and Iron Ore Pricing,' Journal of Industrial Economics, IX, 1960-61, p. 176.
36. Energy, Mines and Resources, Mineral Development Sector, Iron Ore, MR-149, Ottawa, 1976, figure 1.
37. As the result of their equity participation in U.S. mines, Canadian steel producers in fact import ore from the Lake Superior district, amounting to 3.8 million tonnes in 1978, of a total Canadian consumption of 15.3 million tonnes. This compares with total exports of about 45 million tonnes. Energy, Mines and Resources Canada, Iron Ore, p. 219.
38. Ibid, p. 19.
39. Much of the material in this section is derived from the section on iron mining pricing policy in C.H. Pye, Profitability in the Canadian Mineral Industry. (Kingston: Centre For Resource Studies, 1981) pp. 58-63, as well as W.I. Greenwald, 'Supply Shifts and Iron Ore Pricing', and G. Manners, The Changing World Market for Iron Ore, Resources for the Future, 1971.

40. C.H. Pye, Profitability in the Canadian Mineral Industry, p. 59. His sources: Canadian Minerals Yearbook, 1974, p. 238, and Northern Miner, 20 April, 1978 and 19 December, 1978.
41. C.H. Pye, Profitability in the Canadian Mineral Industry, p. 61.
42. Energy, Mines and Resources, Iron Ore, 1978, p. 221.
43. D. Brown 'Mineral Transport' in Canadian Mineral Survey, Energy, Mines and Resources, 1979, p. 23.
44. Home or revert scrap, since it neither appears on the market nor is related to the metal price, can be ignored for the sake of simplicity, as long as its generation remains strictly proportional to metal consumption. A change in this proportion, when a new process such as continuous casting of steel is introduced, will affect the overall scrap market.
45. The negative relationship between D_f and P_f reflects, of course, the standard assumption of a negatively sloped demand curve. D_f and P_{s1} should be positively related because scrap and refined copper are substitutes.
46. If the secondary processor has control over the price of scrap because of limited competition in the industry, it can be shown, given a constant elasticity at scrap supply from dealers, that the marginal product of scrap use will be proportional rather than equal to its price in equation (4).
47. From the Canadian producers' point of view, it is Canadian export demand that is of interest. This is the demand for total primary metal less U.S. primary and other import supply.
48. It has been estimated that secondary copper processing uses 1/10th to 1/25th the energy needed to process the equivalent metal from ores. See P.F. Chapman, 'Energy Conservation and the Recycling of Copper and Aluminum', Metals and Materials, vol. 8, no. 6, 1974.
49. The effects of declining primary ore quality or environmental regulations on smelter emissions could be discussed in an analytically similar fashion, except that in these cases the leftward supply curve shifts would not be accompanied by demand shifts. The former case results only in the primary supply curve shifting upward and the latter in both primary and secondary smelter cost increases. Unlike the case of energy price changes, it is unclear whether smelter emission controls hurt the primary or secondary producer more. These issues have been discussed in several recent articles that will be referred to in the subsequent chapter: for example, M. Slade, 'The Effects of Higher Energy Prices and Declining Ore Quality,' Resource Policy, vol. 6, no. 2, Sept. 1980 and R.S. Hartman et al., 'The Economic Impacts of Environmental Regulations on the U.S. Copper Industry,' Bell Journal, Autumn, 1979.
50. The means that has been employed lately to prevent lower-priced imports from breaking the price discipline of the U.S. firms is the so-called 'trigger price' mechanism, whereby import restrictions are imposed whenever the import price falls below the domestic producer price.

51. See 'Steel Pricing Policies' Planning, vol. XXX, no. 484, Dec. 1964; and C. Higgins, 'An Econometric Description of the U.S. Steel Industry', Essays in Industrial Economics, vol. II, Philadelphia, 1969, p. 1-61. Long-run steel demand is elastic due to substitution in use. See C.K. Rowley, Steel and Public Policy, 1971, chapter 4.
52. The origin of the vertically integrated nature of the U.S. steel industry is described in R.B. Marke, 'Iron Ore and Steel: A Case Study of the Economic Causes and Consequences of Vertical Integration', Journal of Industrial Economics, 19/20, 1970/71, pp 221-229.
53. There is also recycling at this stage, although we have ignored it for simplicity. Blast furnaces also use small amounts of scrap (about 4 percent of the 1979 total) as well as sintered particles.
54. The mathematical conditions and resulting input demands are described in appendix I.
55. U.S. Department of Commerce, Business and Defense Services Administration, 1969, p. 21, quoted in Gordon et al., Nonferrous Scrap: A Literature Review of the Copper and Aluminum Sectors, 1972.
56. The scrap generation ratios for various copper products are shown in table 11 in chapter 5.
57. The average reaction time needed by copper consumers seems to be three-quarters to one year. See MacKinnon and Olewiler (1980), p. 203.
58. The estimated equation related the ratio of brass mill new scrap to refined copper consumption with the relative price of number 2 scrap and LME copper. Number 2 is largely an old scrap price, used as a proxy for number 1 copper or brass mill grade. The equation form was:

$$Ds_1/D_f = 2.86 - 2.85(Ps_2/P_m)t - .510 (Ps_2/P_m)t-1 + .641 \text{ Strike}$$

(-4.8)
(-2.6)
(2.6)

$$\bar{R}^2 = .53 \quad D.W. = 1.75$$

including a variable for strikes in U.S. primary copper. Elasticities at means for the current and lagged prices were -3.13 and -.624 respectively. The equation was estimated by 2sls to reduce simultaneity bias.
59. Except, as we shall see, in periods of export controls on scrap which separate the U.S. scrap market from the London Metal Exchange.
60. Even if the secondary refiners are not competitive (and there are indications in chapter 3 that they are not) under fairly general conditions equation (17) will hold, not with equality but as a constant proportion of Ps_2 .
61. Elizabeth Bonczar et al., An Economic Analysis of the Determinants of Metal Recycling in the U.S., (Harrisburg: U.S. Bureau of Mines, 1975).

62. The Durbin-Watson statistic for our regression is 2.01, while for the Bonczar regression it was .47, and for the CRA regression .59. A value greatly different from 2 indicates the presence of intertemporal correlation of the residual errors, a condition that can be caused by the omission of an important variable.
63. F. Carillo et al., Recovery of Secondary Copper and Zinc, U.S. Bureau of Mines, 1974, p. 8, table 1.
64. Ralph Stone and Co., 'Copper Control in Vehicular Scrap', Los Angeles, 1968.
65. Charles River Associates, Economic Analysis of the Copper Industry, Sept. 1970.
66. Elizabeth Bonczar et al., An Economic Analysis of the Determinants of Metal Recycling in the U.S., (Harrisburg: U.S. Bureau of Mines, 1975).
67. C. Taylor, 'A Quarterly Domestic Copper Industry Model', Review of Economics and Statistics, vol. LXI, no. 3, August 1979.
68. R. Mahulingasivam, University of Toronto (1969), estimated an elasticity of 1.8 in response to differences between the Canadian and U.S. producer prices. This is as expected, and we assume Canadian producers to sell in the USA at the U.S. producer price. He did not, however, estimate the effects of U.S. producer price changes.
69. The grade of ore mined has been taken as exogenous, on the assumption that the best ore is always used first and mines simply move down a fixed grade distribution within the mineable ore. If this assumption is unwarranted (there is some new evidence to indicate that grades of ore mined as opposed to the cutoff grade within the ore may be positively related to metal prices), then our procedure may introduce some statistical bias in the estimated equations.
70. R.S. Hartman et al., 'The Economic Impacts', p. 592.
71. B.E. Felske and Associates, Sulphur Dioxide Regulation and the Canadian Nonferrous Metals Industry, (Ottawa: Economic Council of Canada, 1981), p. 25.
72. The Economic Council study estimated the costs of pollution abatement in Canada at 2-4 cents per pound, based on analysis of information from Hudson Bay Mining and Smelting and Noranda Mines.
73. Hartman assumed the LME price to be exogenous in his simulations, with only the producer price affected by the emission controls. He also ignored any effect of the controls on secondary smelters and refiners.
74. See appendix I.
75. The technique of scrap preheating is discussed in W.F. Kemner, 'The Operating, Economic and Quality Considerations of Scrap Preheating in the Basic Oxygen Process,' Blast Furnace and Steel Plant, 57, December 1969, pp. 1007-1012.

76. Source: Economic Commission for Europe, Problems Relating to Iron and Steel Scrap, (New York: U.N., 1971) p. 30.
77. These regressions, with the rest of the estimated ferrous scrap model, are shown in appendix III.
78. Yields are calculated from J. Sawyer, Automotive Scrap Recycling, 1974, p. 10, and Hogan and Koeble, Purchased Ferrous Scrap, 1977, p. 40.
79. U.S. Department of Commerce, Business and Defense Services Administration, Iron and Steel Scrap Consumption Problems, G.P.O., 1966, p. 48.
80. W. Regan et al., Final Report on Identification of Opportunities for Increased Recycling of Ferrous Solid Waste, Battelle Memorial Institute (ISIS), 1972; and James Sawyer, Automotive Scrap Recycling, Resources for the Future, 1974, p. 11.
81. U.S. Department of Commerce, Business and Defense Services Administration Industrial Scrap Generation, G.P.O., 1957.
82. Hogan and Koeble, Purchased Ferrous Scrap, 1977.
83. Ralph Stone, Copper Control in Vehicular Scrap, Contract 14-09-0070-382, for U.S. Bureau of Mines, Los Angeles, 1968, p. 43.
84. The major U.S. scrap dealers are Laurier Chivany and Devony-Benomo on the east coast, Harman Michels and Joseph's in the mid-west, and Commercial Metals in the west, according to a telephone interview with William Hogan of Fordham University of New York on January 13, 1978.
85. R.L. Adams, 'An Economic Analysis of the Junk Auto Problem', Ph.D. dissertation, University of Illinois, 1972, ch. IV.
86. Sawyer, 'Automotive Scrap Recycling', 1974.
87. From 1971 to 1974, the Iron Age composite number 1 heavy melting scrap price rose from 29.70 per ton to 144.50.
88. We have ignored the effects of ore transport costs in the study. This might partly explain the poorer performance of the Canadian ore demand equation. (See appendix III)
89. Much of the material in this section was derived from discussions with Guillermo Garrido, a chemical engineering student at the University of Waterloo who has completed an M.A. thesis on an aspect of the midrex direct reduction process. Other especially useful sources of information were J.S. Kirkaldy, Ferrous Metallurgy, and G.R. Bashforth, The Manufacture of Iron and Steel, London, 1957, ch. V.
90. D. Barnett, Prices and Costs in the U.S. Steel Industry (Washington: President's Council for Wage and Price Stability, 1977), p. 28.

91. Subsequent to the hearings, the subcommittee instructed the Interstate Commerce Commission (ICC) to rectify the discrepancy. The ICC, however, came down in favour of the railroads, arguing that the rates were not unreasonable or unlawful as long as there was neither a diminished traffic volume nor that it appeared that the scrap industry could not absorb the rates. NARI appealed the ICC ruling to the District of Columbia Appellate Court, where it was first overturned, then finally accepted on higher appeal. See 'Freight Rates May Discriminate Against Recycled Material,' Natural Resource Journal, February, 1980.
92. NARI Newsletter, Washington, D.C.: National Association of Recycling Industries, August 31, 1977). NARI is an umbrella organization comprising the Institute of Scrap Iron and Steel and other scrap dealer organizations.

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